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UNDER THE DIRECTION OF THE
ASSOCIATION OF IRON & STEEL ENGINEERS

Iron and Steel Exposition

THE STEEL INDUSTRY'S MARKET PLACE

Ideal Location

The twenty-first annual Iron and Steel Exposition sponsored by the Association of Iron and Steel Engineers will be held in conjunction with this Society's Annual Convention in the Cleveland Public Auditorium, Cleveland, Ohio, September 27, 28, 29 and 30.

The vicinity of Cleveland, as illustrated, has become one of the largest producing steel centers because the lower costs of shipping finished products to consumers has largely concentrated a great bulk of iron and steel producing capacity along the Great Lakes, the Ohio River System, and the Mahoning and Shenango Valleys. Within a three hundred and fifty mile radius of the city of Cleveland are located 331 major steel plants having 1316 electrical main drives producing 89% of the hot rolled steel products, and 93% of the ingot capacity. Overnight from any steel center in the 350 mile radius, Cleveland is ideally located for the Iron and Steel Exposition. The location of Cleveland combined with the activities of the Association of Iron and Steel Engineers make Cleveland easily accessible to 90% of the executives and engineers directly interested in the production of steel.

Economic Justification

With the assurance of having the representative purchasing influence of the steel industry in attendance at this Iron and Steel Exposition, every manufacturer of steel mill equipment should exhibit in this show.

As shown in the accompanying curve the Steel Industry is continually expanding and modernizing. The application of large motors to main roll drives is one of the best methods of graphically contrasting the expansion of the Steel Industry with steel production. This curve strikingly shows that the Steel Industry is always in the market for better and more efficient equipment. Regardless of the production of steel and the general business condition, steel expansion and modernization continues to go forward. The curve portrays the fact that the Steel Industry has faith in its future. Even during the darkest depression years the Steel Industry is planning the groundwork for immediate and future modernizations.

As an example of the faith the greater Steel Industry has in its future, we can state that fifteen major steel companies reporting a total of $11,732,000,000 in net sales, spent approximately $4,800,000,000 for new equipment and maintenance, during the period of 1929–1936. In annual expenditures alone, the amount expended in 1936, for this purpose, exceeded the amount spent in 1929 by $243,930,000.

In a twelve year period, ending 1937, construction of continuous sheet and strip mills having about 14,000,000 gross tons capacity were completed with a total investment of approximately $350,000,000. There still remains approximately 7,000,000 gross tons capacity of old etyle mills that must be modernized, in order to meet the increased demands of present day competition.

Steel Has Faith In The Future

One large steel corporation displayed faith in the future by spending $407,000,000 for development of various plants over a period of fifteen years. Another smaller plant spent $14,000,000 for plant improvement in 1937. In one depression year another steel corporation spent $5,000,000 for new equipment. In two depression years one large steel corporation expended $87,000,000 for maintenance and repairs to keep inactive departments prepared for resumption of operations when business improved. Contemplated, and uncompleted plans for improvement of one small plant calls for an expenditure of $3,000,000. In a two year period one corporation spent $14,000,000 for maintenance and repairs. Another large steel company made cash expenditures of $45,000,000 in 1937 for additions and improvements to property. The total amount for a three year period for this company was $85,000,000.

Equipment Builders' Opportunity

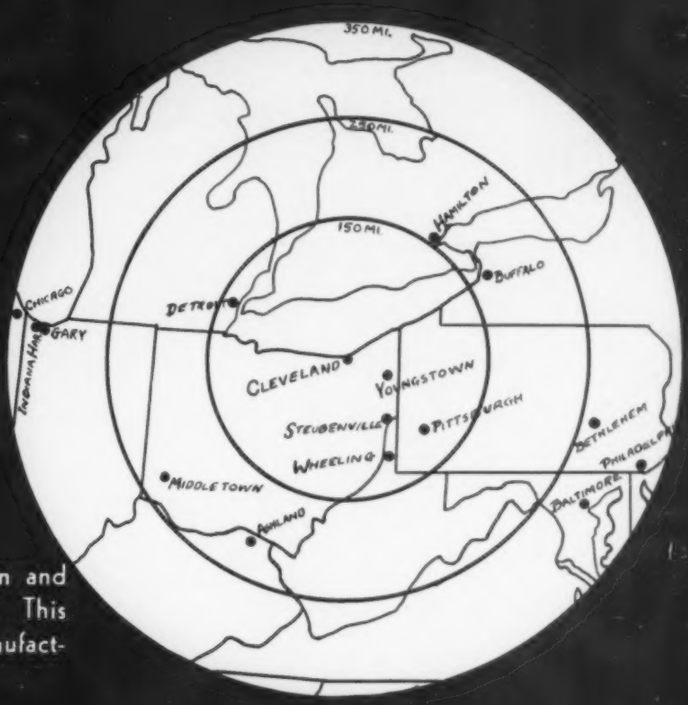
We would like to ask one pertinent question of every sales manager in the equipment industry: IS YOUR COMPANY GETTING ITS SHARE OF THIS BUSINESS? If not you should make plans to meet the men who not only specify the material, but assist in the design, installation, operation, and maintenance of steel mill equipment. The Iron and Steel Exposition, sponsored and controlled by the Steel Industry's only engineering society, offers you the best opportunity of contacting the steel mill executives and operating officials. The Iron and Steel Exposition has repeatedly, year after year, given its exhibitors the best method of contacting and selling prospective customers. Your company must contact these men continually, not spasmodically.

Exhibition Details

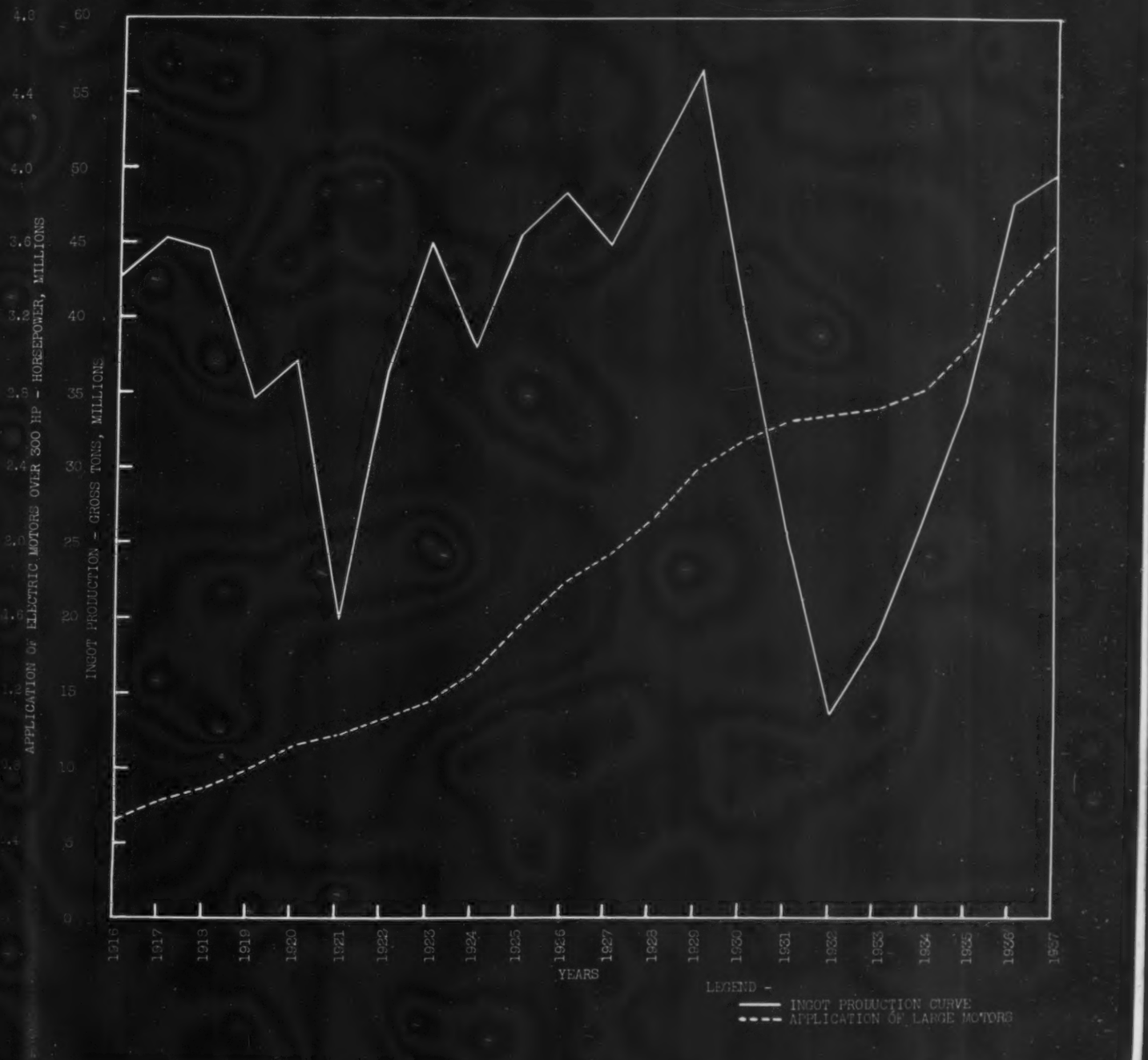
The floor plans as shown on the back page are now ready for selection of space. Prices and other data on services available will be gladly furnished on request. It is suggested that early reservations for space be made, in order to be guaranteed the early choice locations. Please address the Iron and Steel Exposition, 1010 Empire Building, Pittsburgh, Pennsylvania.

Several Display Scenes From 1937 Exposition

Overnight from every great steel center in the country, Cleveland is ideally located for the Iron & Steel Exposition. Its accessibility assures exhibitors of a maximum worthwhile attendance.



Regardless of the production rate of steel, expansion and modernization continues as shown in the curve below. This should be conclusive evidence to the equipment manufacturers of the necessity for continuous sales effort.



FLOOR PLAN
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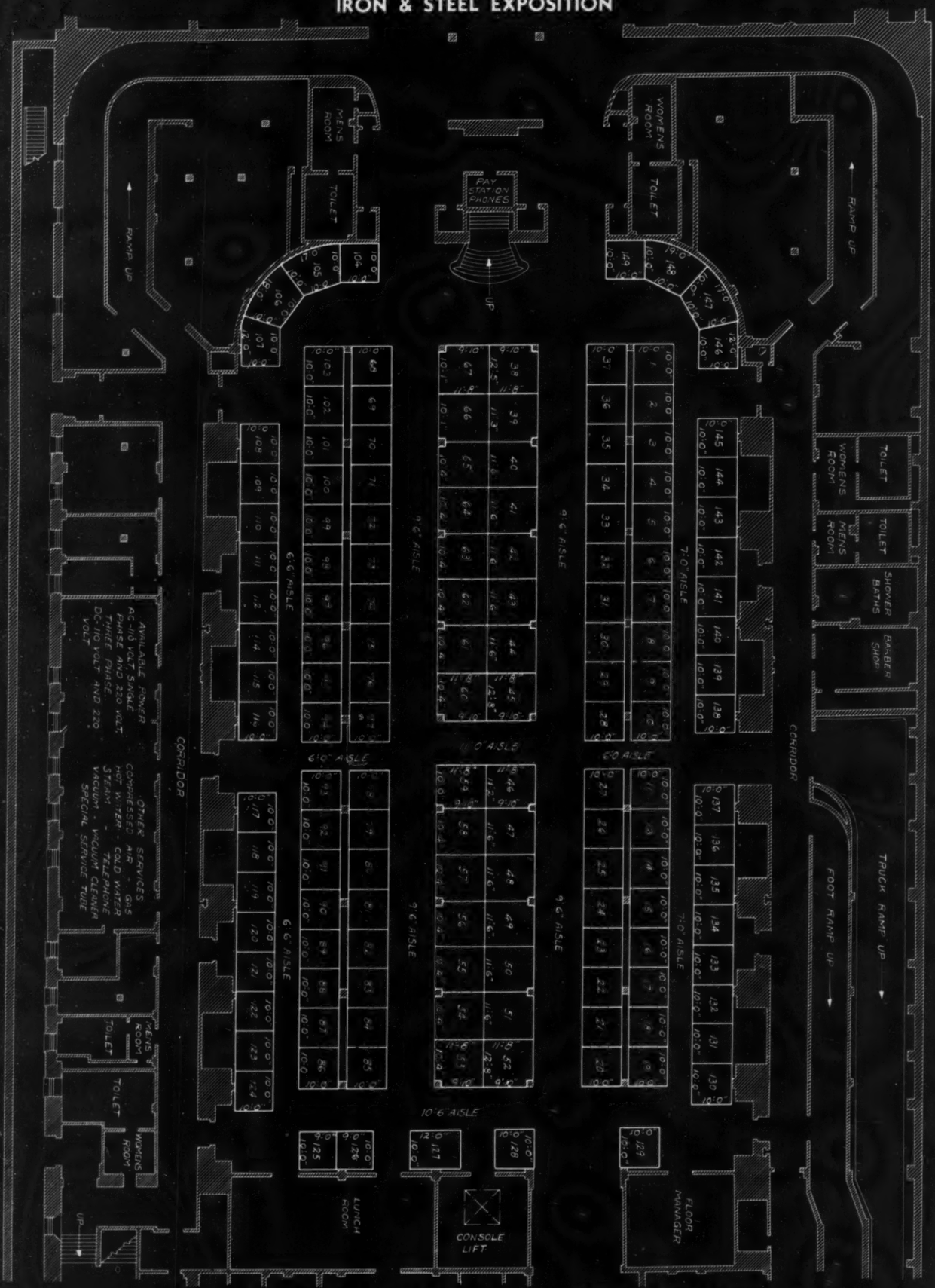

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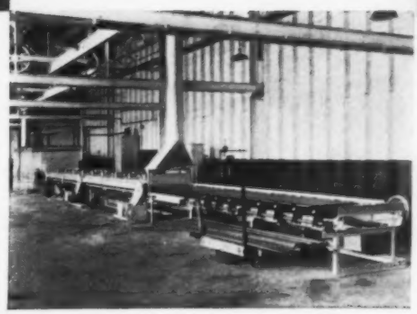
(Below) Various lengths and diameters of steel tubing are uniformly bright annealed in this special atmosphere furnace and automatically unloaded onto trucks.

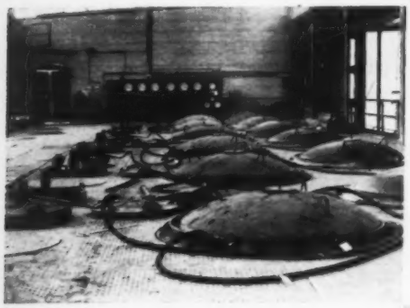
(Above) Another fuel-fired, continuous controlled atmosphere bright annealing furnace equipped with The Electric Furnace Co.'s new recuperative type, gas fired radiant tubes.



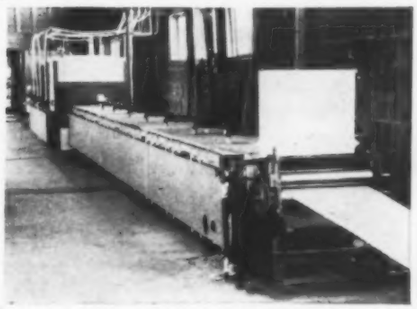
(Above) Special alloy rod is annealed without scale or decarburization in this electrically heated pit type furnace. One of several installations in a prominent steel plant.

(Below) The pit type furnaces shown below are used for normalizing and spherodizing rod, and bright annealing wire—Another "repeat order".

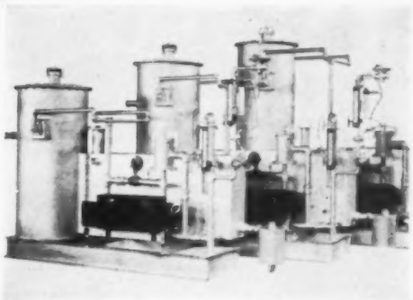
(Below) Bright annealing steel strip—continuously. Advantages include quicker deliveries, shorter annealing time, absolute uniform finish and anneal. These furnaces handle either narrow or wide strip.



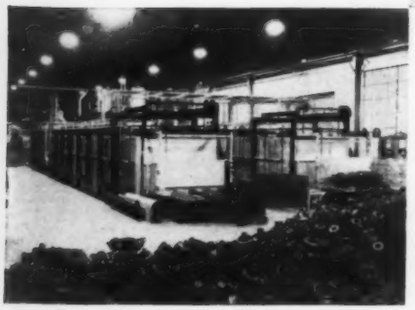
(Below) Three standard sizes of Elfurno generators for producing the inexpensive protective atmospheres used in controlled atmosphere furnaces. Elfurno generators are built for any capacity required.



(Below) Short cycle malleable castings are annealed absolutely scale-free in these two continuous special atmosphere electric furnaces. The annealing time was reduced from 165 to 35 hours. These furnaces handle 40,000 lbs. per day.



(Below) Bolts, nuts and miscellaneous other medium sized parts or products are scale-free hardened in continuous chain belt conveyor type furnaces similar to the above. This furnace handles 1000 lbs. per hour.



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By L. A. UMANSKY

Industrial Department

GENERAL ELECTRIC COMPANY

Schenectady, New York

Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

▲ THE writer believes in the advantage of applying d-c motors for driving the runout tables and coilers of modern wide and fast hot strip mills. Under this system each roller or each pair of rollers is equipped with a mill type d-c motor, ranging in capacity up to 7.5 or 10 hp. in case of tables, and up to 25 hp. in case of coilers. These motors are subdivided in groups (up to 60 or more per group), and each group is supplied with power from a d-c generator. Ward Leonard control is used to start, accelerate, slow down, stop, or reverse each table section of each coiler.

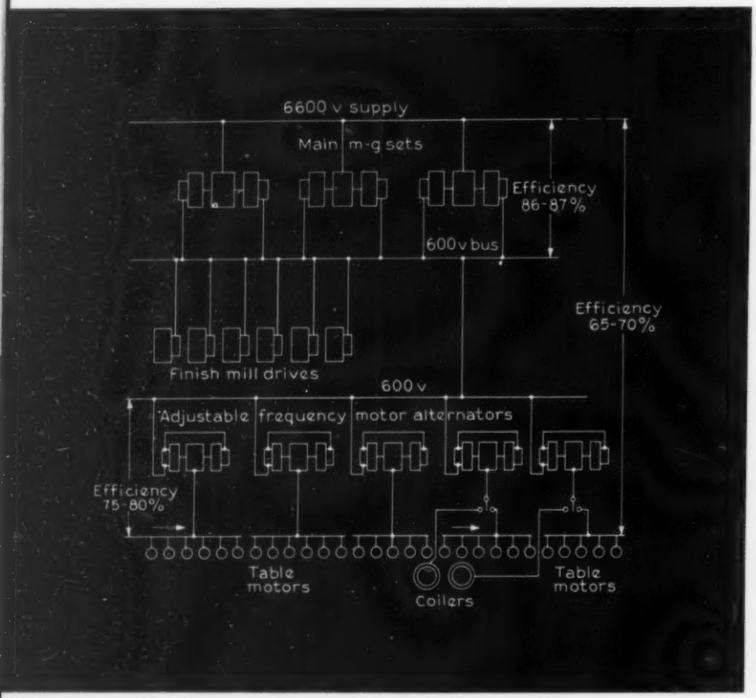
The writer has suggested this system late in 1936, in connection with the then proposed 98-inch hot strip mill,—in preference to the previously considered standard method of using squirrel cage induction motors and adjustable frequency M-G sets. Since that time not only the 98-inch mill in question, but a 44-inch and an 80-inch hot strip mill were laid out and ordered with d-c motors for tables and coilers.

What is the reason for this apparent change in trend from a-c to d-c? The present paper attempts to answer this question as the author sees it.

The idea of individual drives for table rollers is more than 25 years old. The Company with which the writer is associated has built them since 1911. The mills considered in the earlier years were either strip or hoop mills, or merchant bar mills. The table rollers were light and short. Each required a motor of, say, ¼ hp. or ½ hp., and the aggregate capacity seldom exceeded, say, 100 hp. or 200 hp. Table rollers were ordinarily kept running continuously. Under the circumstances, it was most logical to make these small motors of squirrel cage type, and to control their speed as a unit from time to time by raising or lowering the supply frequency. This system is well known to all of us. Many very able papers were presented before the Association dealing with drives of this type.

With the advent and growth of the wide strip mill the capacity of the table and coiler drives grew by leaps and bounds. In some cases the total capacity of motors has been over 2000 hp. for a single-line table. The several table sections and the coilers must be individually started and stopped. The converting plant consisting of d-c to a-c motor-generator sets included in some cases six or more sets, aggregating well over 3000 kva.

FIGURE 1—Power circuit of a-c motor driven runout tables and coilers at a hot strip mill. Note four transformations of power from a-c supply to motors.



POWER CONVERSION

Its first and inherent handicap is that of any adjustable speed a-c drive. We all agree, and rightly so, that the squirrel cage motors are simple, rugged, and therefore desirable. However, the only means of adjusting their speed is by varying the applied frequency. There is no good and practical means as yet developed of providing commercially a source of adjustable frequency. It is quite certain that if we could control the a-c frequency as simply as we control, say, the generator voltage, we would not be discussing today the d-c drives. But such method of frequency control has not been sufficiently developed as yet, and we still must rely on the old and rather crude way of providing adjustable frequency by means of d-c to a-c motor-alternators.

Figure 1 shows in a simplified way the power conversion system in case the runout tables and coilers are a-c driven. Several large M-G sets supply 600 volt

DRIVES *for* RUNOUT TABLES *and* COILERS

d-c power to the finishing stands of a hot strip mill. Thus far we have two power conversions (a-c to mechanical, mechanical to d-c power). While the full load efficiency of these large sets is around 90%, the average operating efficiency can not be expected to be much better than 86–87%, if that high.

Part of this 600 volt d-c power is diverted to several M-G sets consisting of adjustable speed d-c motors driving alternators. This means two additional power transformations, and much less efficient at that. The d-c driving motors, with speed controlled by shunt field, are essentially constant horsepower machines, but their load varies with speed; hence the load factor and efficiency are rather low at the minimum and average speeds. Likewise, the alternators operate at such low power factor as 50–70%, which fact increases the machine losses. Certainly the average operating efficiency of such a set is not greater than 75–80%. Thus, the overall efficiency, from a-c supply to table or coiler motors, is not more than 65–70%, if that much.

The Fig. 1 illustrates a rather conventional arrangement of a hot strip mill with a straight-away table subdivided in five sections and with two coilers. Five motor alternators are employed, the last two being used alternatively either with the coilers or with the piler table sections. Dynamic braking set and control apparatus are purposely omitted.

On Figure 2 the same table and coilers are shown, but equipped with d-c motors. Instead of five motor alternators operating from the 600 volt bus,—one set can be employed. It consists of a synchronous motor operating directly from 6600 volt or 2200 volt supply and driving five d-c generators. The latter are assigned to the several table sections and coilers in exactly the same manner as in the previous case. Now, the full load efficiency of such a set is again close to 90%, with the average operating efficiency around 85%. Thus, if we assume for a moment that both the d-c and a-c motors require the same amount of power brought to them, and if we call this amount 100%, then the conversion losses from a-c supply to table motors are about 50% in the case of a-c drives, and only, say, 20% in the case of a d-c system.

Records show that tables and coilers of a large and high speed strip mill equipped with a-c drives on a single straight away table consume close to 4 kw-hrs. per ton rolled, the power being measured at the 600 volt bus. For a more elaborate system of tables, with broadside transfers, etc., this figure is apt to be still higher. Given a production of 75,000 tons per month,

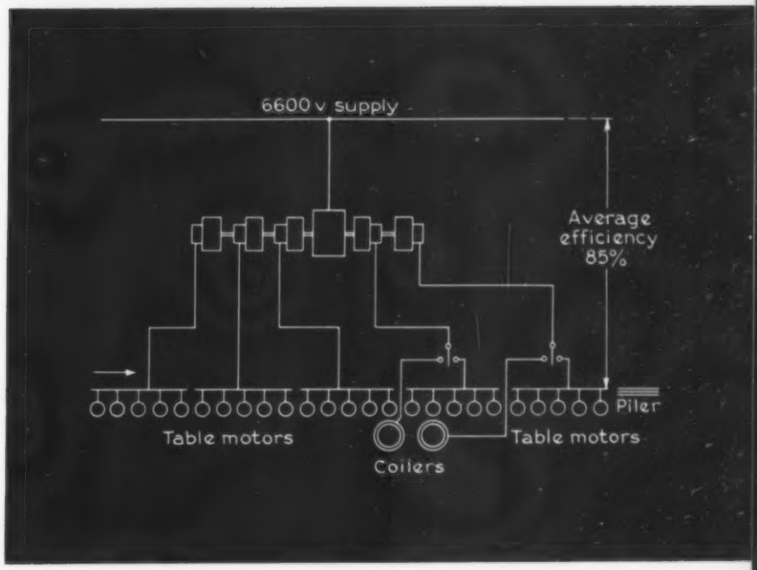


FIGURE 2—Power circuit of d-c motor driven runout tables and coilers at a hot strip mill. Note that only two power transformations are used from a-c supply to motors.

we deal with a figure of 3,600,000 kw-hr. per year of 600 volt power, or over 4,000,000 kw-hr. at the high voltage bus. Assuming again for a moment that the d-c table and coiler motors themselves consume as much power as the a-c motors, the power saving, due to reduction of conversion losses alone, may be readily evaluated in this case at more than ¾ of a million kw-hr. per year.

But we will presently see that actually the a-c motors operating on a start-stop, or frequently accelerating and decelerating cycle, consume more power than d-c motors performing the same duty, and impose another burden on the power bill.

EXTRA ACCELERATING LOSSES IN A.C. MOTORS

It is well known that a squirrel cage motor, simple and therefore attractive as it is, is not particularly well adopted for a rapid start-and-stop service. Such a motor, connected to an inertia load and started at full frequency, will absorb as heat in its rotor as much energy as the kinetic energy of rotating masses at full speed. Plug this motor and bring it and the load to rest—and you absorb in the rotor three times that amount of energy. Or, cut it off the line while running and stop it by d-c dynamic braking—and again you put into the rotor as much heat as you did while starting. All this is over and above the ordinary or running losses of the motor. Since the WR^2 of table rollers of a wide strip mill is quite appreciable, the amount of these extra losses overheats the motors, or calls for bigger motors than are otherwise necessary.

A simple example will well illustrate this point. Assume a section of a runout table extending from the last mill stand to the coilers and arranged for a broad-

side transfer. In other words, this table must be stopped for each bar and re-started again. This cycle may be repeated twice a minute.

The table consists of, say, 150 rollers, each with a $WR^2 = 250$ lb-ft^2. A delivery speed of 2000 fpm calls for 638 rpm at the roller. The stored energy of rotating parts (neglecting the weight of the strip) is 32 hp-sec. The control is arranged—wisely or otherwise—to start the motors at full frequency, and to stop them by applying d-c dynamic braking at full speed. The extra rotor losses which we have just mentioned, amount in this case to 128 hp-sec. per motor every minute, which is equivalent to 1600 watts steady loss per motor. Now, suppose we want to employ in this case a 10-hp motor per roller. With an efficiency of 85%, it is capable of dissipating steadily a loss of only about 1310 watts. Hence, we must greatly increase the size of the motor—just to dissipate these extra losses, or a total of about 2900 watts. As soon as we increase the motor size, we increase the current inrush on starting, and we must probably increase the size of the alternator—strengthening all links in the chain.

Now if we were starting and stopping not a squirrel cage motor, but a slip ring motor or a d-c motor with magnetic control, the same "extra" losses would appear in the starting resistor. We would not have saved on power, even though we would save on motor heating. But with a d-c motor, Ward Leonard controlled, we eliminate these extra losses and heating altogether.

Hence, we see why a smaller continuous rating of d-c motor is required to operate on a frequent start-and-stop, or speed-up and slow-down cycle, everything else remaining equal. If, say, a 10-hp squirrel cage motor will barely get by, then a 7.5-hp d-c motor is apt to be more than ample for the same application. This is not, by any means, a new finding. Anyone familiar with motor applications for cranes, hoists, mill auxiliaries, etc., will readily recognize in it a well known and established fact that a smaller d-c motor will do the work of a considerably larger a-c machine.

The extra rotor losses of squirrel cage motors do more than overheat the machines. They result in an outright loss of power. Since the power must be supplied through several stages of transformation, the losses are multiplied and result in such extra tax on the "coal pile" of which none of us can be proud.

For instance, in the above example the extra losses are 32 hp-sec. per motor for each start. For 150 motors and two starts per minute, these losses equal 119 kw-hr. each hour at the table, or say 175 kw-hr. per hour at the high voltage bus. With the d-c motors not only is this power saved, but an additional amount, say, 50% is recuperated through regenerative braking; this makes a total gain of over 250 kw-hr. per hour. Suppose the mill operates in this manner only 3000 hours per year. This will give us an extra debit against the a-c system of 750,000 kw-hr. per year,—over and above the extra conversion losses estimated previously at a like figure, making a sizable total of 1,500,000 kw-hr. Allow 0.7 cents per kw-hr. and you have an extra annual power bill of about $10,000.

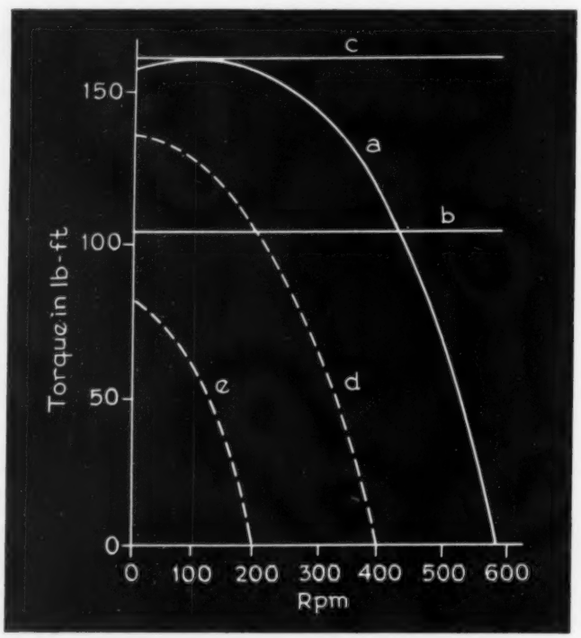


FIGURE 3—Speed-torque curves of squirrel cage table motor when starting: (a) at full frequency; (d) at ⅔ frequency; (e) at ⅓ frequency. (b) is an equivalent torque of a d-c motor which will accelerate the load as fast as the a-c motor with torque (a). (c) is the torque of a d-c motor with same maximum torque as a-c motor (a).

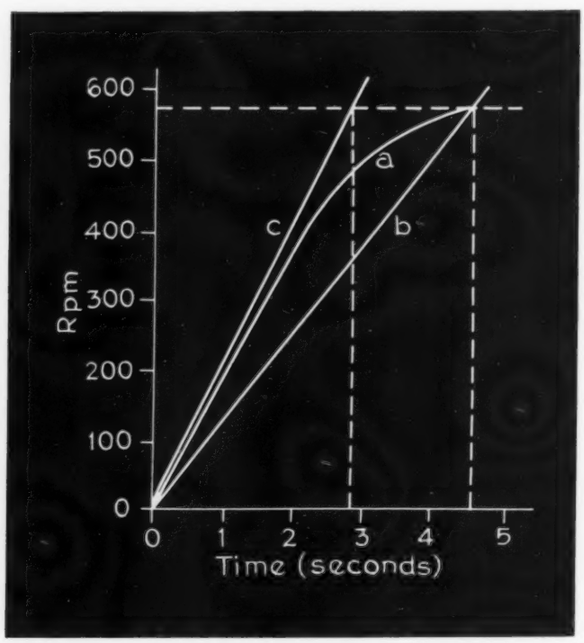


FIGURE 4—Time required to accelerate the table by means of: (a) a-c motor; (b) d-c motor with the same average torque; (c) d-c motor with the same maximum torque. Torque values same as given on Figure 5.

FREQUENCY CONTROL

It is often possible to reduce the extra starting and stopping losses of squirrel cage motors by applying the so-called "frequency control." Its advantages were very clearly presented before the 1935 Convention by Messrs. Hildebrand and Snyder.

Under this system, with the table or coiler at standstill, the motor-alternator is idling at its minimum speed and frequency (usually ⅛ to ½ of the maximum). The motors are started at this low frequency, and then the motor-alternator is accelerated, carrying the table motors with it. Likewise, to stop the table the M-G set is decelerated to minimum speed, reducing thereby the table speed, after which the table motors are disconnected and brought to rest by dynamic braking or plugging.

This reduces very materially the extra losses and heating in the table motors, but leaves them still much higher than in d-c machines. As far as power consumption goes, the corresponding reduction can not be fully realized; the frequent acceleration and retardation of the motor-alternator with relatively low overall efficiency consumes an appreciable amount of power, increases its heating, and imposes an additional burden of the commutating capacity of the d-c motor driving the set. This motor, or rather its commutator, becomes the neck of the bottle of the whole system.

ACCELERATING TORQUE

A d-c motor separately excited and started by raising the applied voltage is capable of producing a substantially constant torque from standstill to maximum operating speed. Thus, the terms "maximum" and "average" accelerating or retarding torques coincide in this case.

With a squirrel cage motor the situation is different. The torque varies with the speed,—whether the motors are started at full frequency or by frequency control. The average torque is always lower than the maximum one. Hence, the obvious rule: A d-c motor having the same maximum torque as an a-c motor develops a greater AVERAGE accelerating torque and will, therefore, accelerate or stop the table or the coiler faster. Or, to put it differently, for the same average torque the d-c motor can afford to have a somewhat lower maximum torque than its a-c competitor.

For instance, on Figure 3, the curve "a" represents the torque of a squirrel cage motor plotted as the function of its speed. The maximum torque is 160 lb-ft. On Figure 4 the curve "a" shows the speed-time function of this motor, connected to $WR^2 = 250$ lb-16 ft^2 (friction neglected); it is estimated that it will take about 4.5 seconds to come to 570 rpm, or 95% synchronous speed.

Now a d-c motor, with a uniform torque "b", in order to accelerate to same speed in same time, will require a torque of only 103 lb-ft. Or, if its torque "c" equals the previous maximum of 160 lb-ft, it will bring the roller to 570 rpm in about 2.9 seconds.

Likewise, on Figure 5 and Figure 6 the stopping of two types of motors is compared. The squirrel cage motor is assumed to be stopped by dynamic braking (curve "a"), with the maximum torque again equal to 160 lb-ft. This requires 4.9 sec. (friction neglected).

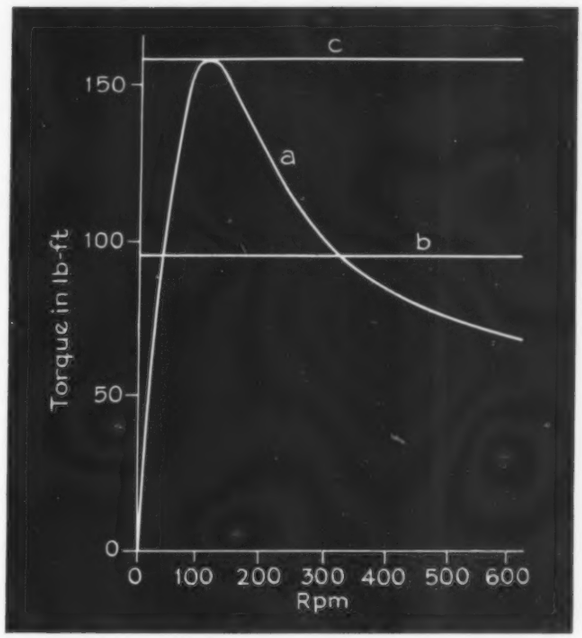
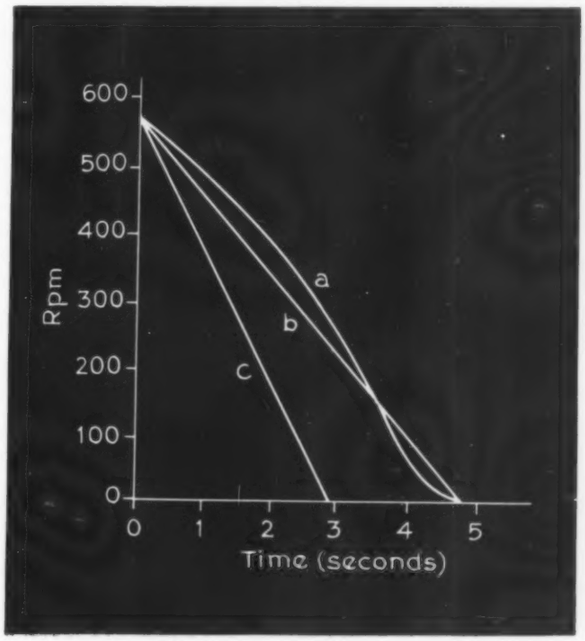


FIGURE 5—Speed-braking torque of: (a) a-c motor with d-c braking applied; (b) equivalent d-c motor; (c) d-c motor with same maximum torque as (a).

A d-c motor, in order to stop in the same time needs a uniform torque of only 95 lb-ft. But if its torque is again equal to the a-c maximum (curve "c"), then it will stop in 2.9 sec.

If the a-c motor is operated by frequency control, then its maximum torque is far from being the same at all frequencies. For instance, (see Figure 3) the

FIGURE 6—Time of stopping the table by: (a) a-c motors and d-c braking; (b) d-c motor with same average torque; (c) d-c motor with same maximum torque as (a). Torque values same as given on Figure 5.



same motor operating at ⅔ frequency, curve "d", has a maximum torque of only 135 lb-ft; at ⅓ frequency, curve "e"—only 82 lb-ft. Thus, in dealing with a-c motors we should carefully stipulate what maximum torque we are talking about. With a d-c motor the maximum torque is always a definite term.

The non-uniform shape of torque-speed curve of a squirrel cage motor (particularly when stopping by means of dynamic braking) has two additional shortcomings.

In the first place, when the maximum torque differs very much from the average, it is questionable whether the latter is a true average at all. The point is that when the peak braking torque is developed, the rate of retardation might be excessive, and the strip may actually slip on the rollers, the table stopping faster than the metal on it. When the torque is uniform, as with a d-c motor, we may get the ultimate possible rate of retardation throughout the period and the quickest stopping (or acceleration) of the strip.

Secondly, a torque which is not uniform produces considerably more strain on the mechanical parts. Cases are known when shafts were twisted, or gears were stripped when the retarding torque of an a-c motor, under control of dynamic braking reaches its high maximum,—which is provided to keep up a reasonably high average.

It is reasonable to expect that the smooth Ward Leonard control used with the d-c motors will reduce the mechanical maintenance as much as it did for blooming mill auxiliaries for which it was recently introduced.

Then, we may well remember another well known fact: A voltage drop reduces the a-c motor torque as a square of voltage, while that of a d-c motor is independent of voltage. When a group of a-c motors is thrown on an alternator, the current inrush may pull the voltage down, in spite of field forcing usually employed. Suppose we get only 90% of the rated voltage at the motor. It will then develop only 81% of its nameplated torque.

But the d-c motor will always give 100% of this value.

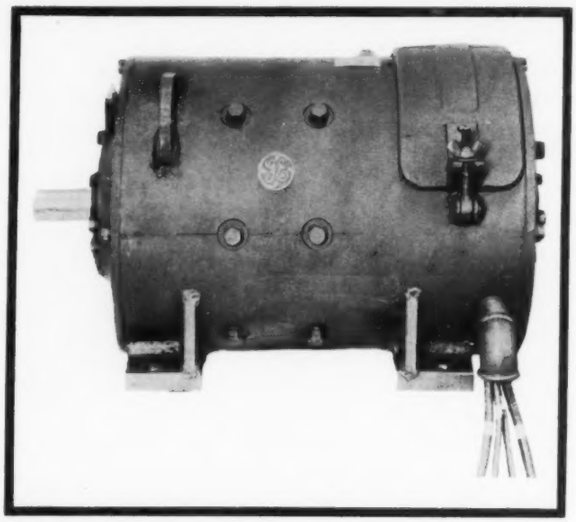


FIGURE 8—Close-up view of table motor as shown on Figure 7.

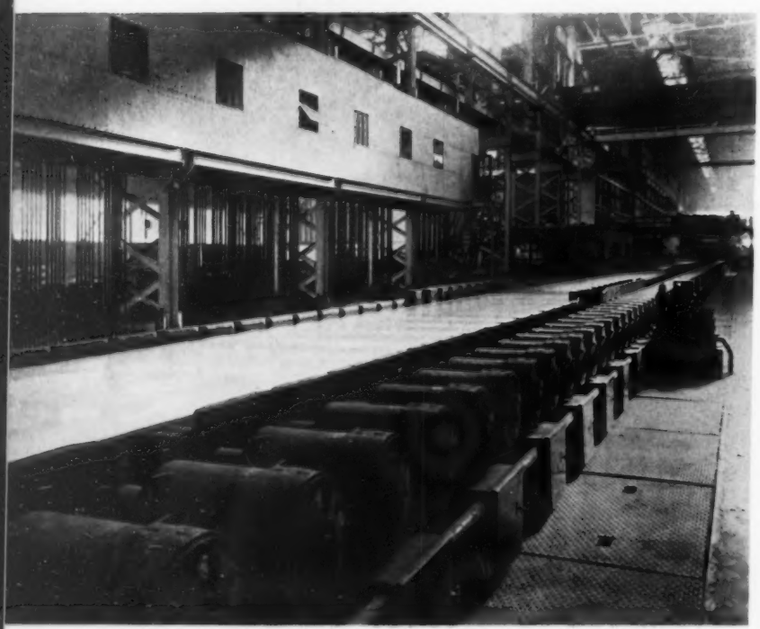


FIGURE 7—General view of runout table at 98-inch hot strip mill (Republic Steel Corp.). Each 12″ x 98″ roller driven by a direct coupled d-c mill motor. Maximum starting torque—140 lb-ft; maximum speed—750 rpm at 250 volts.

KEEPING MOTORS IN STEP

Several squirrel cage motors, connected to a common frequency supply and carrying about same load, run at substantially same speed, i.e. in step with each other. Will the same condition exist in case of d-c table motors?

It will. All of these motors are operated at constant excitation. The entire speed range is covered by voltage control. All motors are checked at the factory to operate at same speed for a given voltage. Tests show that the variations in this respect do not vary more than 1-2%. In other words, the d-c voltage determines the speed of several motors as positively as the a-c requency.

But will the several motors comprising a table section operate at the same voltage? What about voltage drop in the feeder bus running parallel to the table? Simple calculations will readily show that this drop is negligible, usually less than 1 volt.

Therefore, it is not only possible, but it is even not difficult to keep the several motors of a table section or of a coiler in proper step with each other.

The question of matching speeds of adjacent table sections, or of the table and the mill, etc., is solved just as easily with either d-c or a-c systems. In one case it is the d-c generator voltage which is to be adjusted; in another case—it is the speed of d-c motor driving the frequency set. One relies on d-c in either case.

In designing coiler motors the question of necessary slip usually comes up. Opinions vary whether a flat or a drooping characteristic fits this drive best. With squirrel cage motors it was found necessary on a few occasions to change the rotors in order to alter the

motor slip,—incidentally interfering with the motor torque. With the d-c drives such adjustment is elementarily simple: A light differential series field on the d-c generator can be easily adjusted; or a small amount of line resistance for each coiler motor can be provided to suit the local requirements,—a good illustration of flexibility of the d-c system.

EFFECT ON 600 VOLT SYSTEM

The adjustable frequency motor-alternators require a source of d-c power. In case of wide hot strip mills it has been customary to tap for this purpose the 600 volt supply available for the finishing mill. As long as the capacity of the motor alternators was small, the effect of this load on the 600 volt system could be neglected. But when the aggregate capacity of d-c motors on these sets reaches, say, 2000 or 3000 hp, or more, with peak load much higher,—then we must recognize this fact and increase by suitable amount the capacity of the main M-G sets.

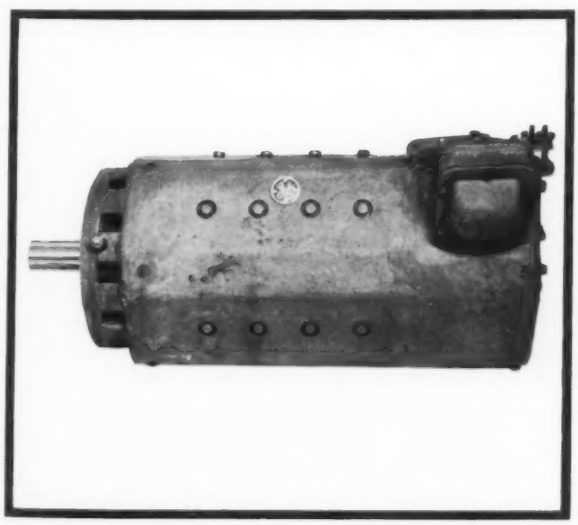
In a modern wide strip mill this extra load is about 1000 kw on the average with a peak up to 3000 kw, or more. The peak load on the motor-alternators usually coincides with the load on the finishing stands. Thus, we can not rely unduly on the assumed diversity factor. The capacity of the M-G sets should be increased by not less than 1000 kw. This may add $20,000–25,000 to the first cost.

SUBSTATION SPACE

With the a-c system we ordinarily require as many or more motor-alternators as we have table sections. For instance, on Figure 1 we have shown five such sets. Add to this a dynamic braking set, a large control board with heavy a-c contactors—and you can not get by with less than, say, three 25 x 65 ft. bays in the motor room—or with an equivalent space elsewhere.

The a-c to d-c set shown on Figure 2, with Ward Leonard control board, will easily go in a single 25 x 65 ft. bay,—saving over 3000 sq. ft. of valuable space. Even at $5 per square foot this gives you a $15,000 saving.

FIGURE 10—Close-up view of d-c mill type coiler motor as seen on Figure 9, 25 hp—700 rpm—250 volts.



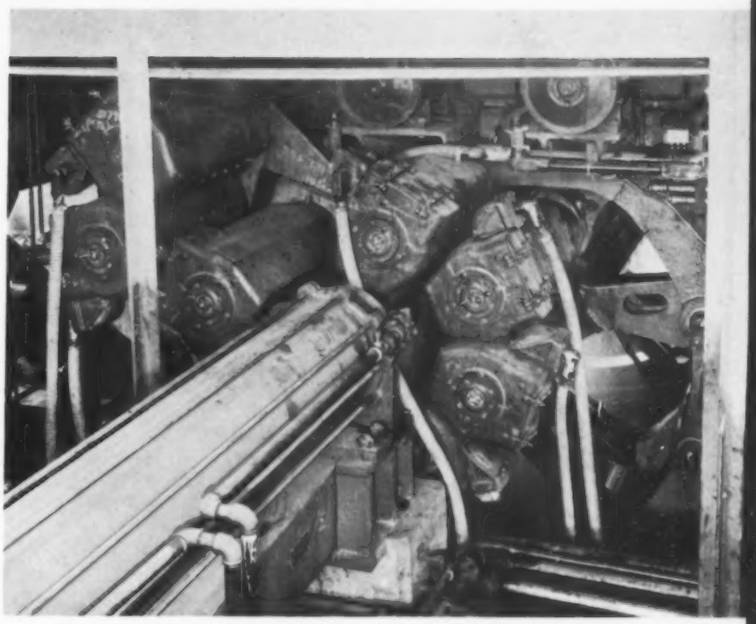


FIGURE 9—Hot strip coiler at 98-inch mill of Republic Steel Corp. Driven by nine d-c mill motors, each rated 25 hp—700 rpm—250 volts.

TYPE OF MOTORS

If we apply d-c motors for driving these tables and coilers, it would be careless, of course, to select for this purpose what is known as an industrial or general purpose type of motor. We should not expect the steel mill engineers to be satisfied with anything less than a mill type motor,—similar to the one which this Association standardized on some ten years ago.

Class B insulation should be, of course, used throughout. Heavy shaft and anti-friction bearings are in order. Table motors—and especially the coiler motors—should be made practically water tight. Several photographs illustrate such motors already built for a 98-inch mill and a 44-inch mill.

Then, of course, the motors should be designed for heavy peak loads,—as is customary for mill type motors. For instance, the illustrated table motor can easily and repeatedly develop torques of over four times normal. On the test stand it has developed many times a stalled torque of seven times normal.

These machines can be built with feet, for connection to the rollers through a flexible coupling, or as flange mounted machines either for coupling or gearing. In fact, any type of mounting can be readily adopted.

A d-c motor need not have a round frame, like an a-c machine. It can be given some very peculiar shape to fit the usually limited space available. In this respect they give much more leeway to the designers than the squirrel cage machines.

The illustrated motors are totally enclosed, without external ventilation, without fan-cooled or water-cooled

FIGURE 11

FIGURE 12

FIGURE 13

features. This results in the simplest construction and installation which should be favored for the time being. Of course, forced ventilation can be readily applied if otherwise desirable.

FIRST COST

D-c motors cost more than squirrel cage motors. On the other hand, the a-c to d-c motor-generators and Ward Leonard control equipment are materially less expensive than the motor-alternators and heavy a-c control.

The greater the number of separately controlled sections into which the tables are subdivided—the greater is the price advantage in favor of the d-c system.

Taking the equipment as a whole, the two types of drives are usually competitive in price, even neglecting the pro-rated cost of the 600 volt M-G sets. With the latter figure thrown in—as it should be—the scales usually tip definitely in favor of the d-c system.

MAINTENANCE

The writer readily concedes the point that a d-c motor requires more maintenance than a squirrel cage motor, on account of brush wear. How much more—is something which should be better answered next year by actual records. But, it is of interest to mention one fact. An analysis was made of the total cost of brushes,—first on d-c table motors and their d-c generators and, secondly, on the motors driving the adjustable frequency sets and on the dynamic braking set. This extra cost was only $300–400 greater in case of a d-c system. Since the brushes should last at least a year, the argument of extra maintenance loses some of its potency.

As every operating man knows, the maintenance expense for any drive is that for motor and FOR CONTROL. The latter is so much simpler and is working so much easier with the Ward Leonard controlled d-c motors that it is very questionable whether the total maintenance expense will be higher with the d-c system.

We may just as well remember that the steel mill engineers have been selecting for their toughest jobs the mill type d-c motor. Who would, for instance, consider even half-seriously applying an a-c motor to a blooming mill screwdown, to a sideguard, or to an open hearth charging machine? Why do we make this choice even though we realize that a-c motors are free from commutators and brushes? The answer is only one: We do it because we know that a d-c mill motor and control will do a better job and with less total expense than an a-c motor and control. The writer is

FIGURE 11—D-c mill type motor for driving two table rollers at a 44-inch hot strip mill. Motor is flange mounted and carries a pinion engaging two gears on table rollers. Rated 7.5 hp—1750 rpm—250 volt.

FIGURE 12—D-c mill type motor, "ceiling mounted", direct coupled to table rollers over coilers. Rated 3 hp—525 rpm—250 volt. Used at 44-inch mill.

FIGURE 13—D-c mill type motor, flange mounted, for driving strip coilers at 44-inch mill. Five motors used per coiler, each rated 10 hp, 1200 rpm, 250 volt.

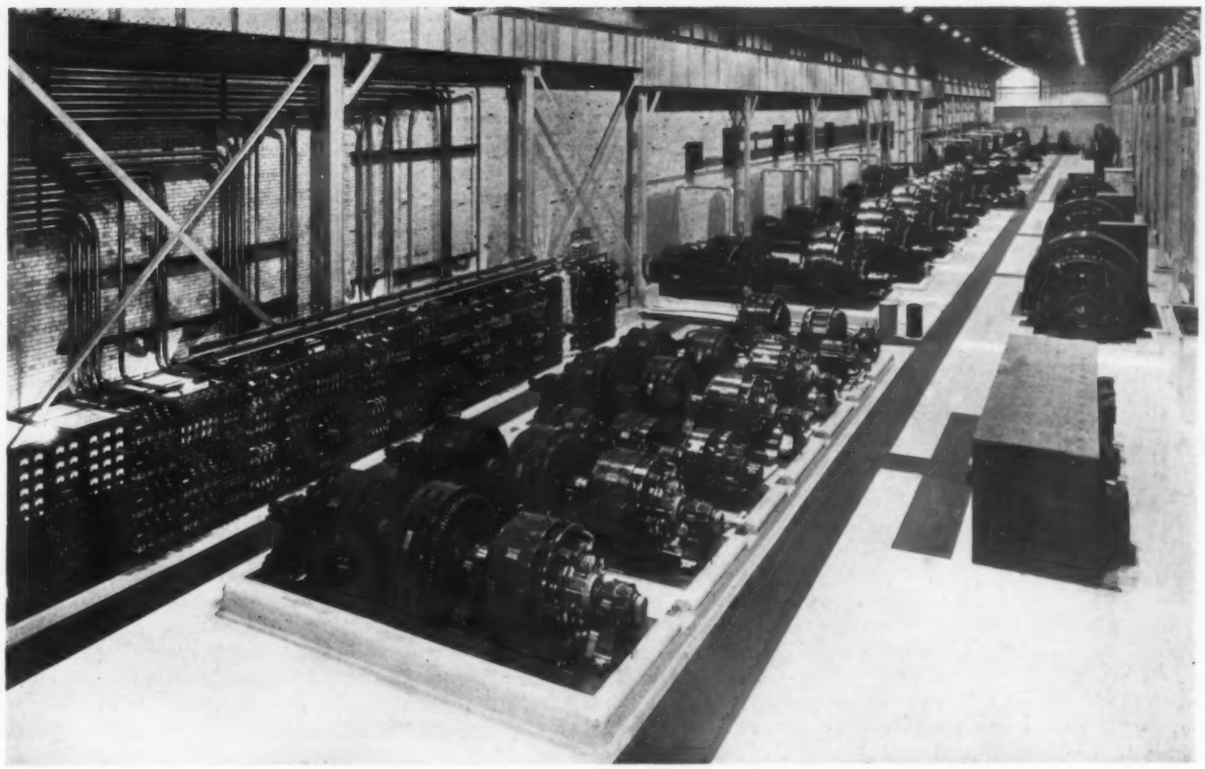


FIGURE 14—Motor room of a modern 96-inch hot strip mill. Motor-alternators and control for a-c driven tables and coilers shown in foreground.

reasonably certain that the runout table and coiler drives for wide, high speed strip mills will not prove an exception to this rule.

CONCLUSION

It is very far from the writer's intention to advocate the use of d-c drives for all runout tables regardless of size. He still believes that when the amount of power involved is relatively small, and when starting and stopping is not frequent,—the a-c motors will hold their own. The writer's primary purpose is to point out the salient features and certain advantages of the new system. It is always better to have on hand two tools instead of one.

The writer is equally certain that this "new system" will not remain "new" for very long. Someone will probably suggest and build something better, and more efficient. We will welcome such improvement,—because this will give us a stimulus to do something still better.

Good engineering is still based on the old principle: Never follow blindly a beaten path—there is always a better way.

This story would not be complete unless proper recognition is given to the steel companies who have made this new application possible. It requires a great deal of engineering judgment and courage to break away from precedents and to risk the success of a $15,000,000–20,000,000 mill by equipping it with something attractive as it is on paper but not yet tried out. To the management and engineers of the Republic Steel Corporation, the Inland Steel Company, and the Carnegie-Illinois Steel Corporation the writer pays tribute,—respecting their courage, appreciating their confidence, and sharing their expectations.

FIGURE 15—Motor room of 98-inch hot strip mill of the Republic Steel Corporation, the first to employ d-c drives for tables and coilers. The motor-generators and control for flying shear, tables and coilers shown in foreground.

DISCUSSION

PRESENTED BY

E. G. SCHLUP, Electrical Engineer, American Rolling Mill Company, Middletown, Ohio

A. M. MacCUTCHEON, Vice President, Reliance Electric & Engineering Company, Cleveland, Ohio

H. W. NEBLETT, Engineering Department, Inland Steel Company, Indiana Harbor, Indiana

J. FARRINGTON, Electrical Superintendent, Wheeling Steel Corp., Steubenville, Ohio

L. A. UMANSKY, Industrial Department, General Electric Company, Schenectady, N. Y.

E. G. SCHLUP: I agree with Mr. Umansky in the advantage of DC motors for certain runout table applications. I am familiar with a very recent installation of an 80″ runout table. After careful cost analysis, depending on local power conditions and operating requirements of the table, it was decided to install an AC drive. No standby AC generating capacity was provided since 25 cycle and 60 cycle shop power circuits are available for emergency. A Ward-Leonard DC system requires some standby generating capacity or an oversized initial installation.

With reference to the maintenance cost of the DC motors, I feel that it will be considerably higher than for AC motors based on experience. Breathing trouble on motors experience on very undesirable locations will result in more frequent breakdowns of the DC motor.

I agree with Mr. Umansky that a proper cost analysis of the maintenance item for the two systems can only be made after a year or so of operation of the DC system.

A. M. MACCUTCHEON: I wish to compliment Mr. Umansky on the timeliness and excellence of his paper, and to record that there are no fundamental statements with which I disagree.

As Mr. Umansky states, individual drives for runout tables have been in use for many years. It is also correct that the variable voltage Ward Leonard system has been most successfully applied for many years. There are many such drives in the steel mills, operating blooming mills, blooming mill tables, galvanizing takeup frames, shear tables, etc. Over the last fifteen years, there has been a considerable increase in the use of such drives in all industry. They have been recommended and applied to paper machines, paper calenders, textile range drives, and for many other applications. This system has served admirably whenever a group of motors was to be operated at a varying primary or delivery speed. There have been certain disadvantages relating to cost and maintenance, but this type of drive has been used whenever there seemed to be an economic justification.

Whether a specific table should be powered by varying frequency a-c. or varying voltage d-c. can be determined only after a thorough study and analysis, in which all economic factors are recognized, evaluated, and properly balanced. The problem is an economic one.

There are certain inherent and readily-recognized advantages in the use of a-c. motors. Until the compensating advantages of d-c. motors are demonstrated, a-c. usually has had the first choice. This is clearly seen in the history of electrical installations throughout the steel industry. While d-c. was first used, as alternating-current distribution systems were introduced, there came a rather general turning toward a-c. because of its obvious advantages; then a reconsideration and recognition that for many applications d-c. was justified. Today, every new steel mill is equipped with both d-c. and a-c.

As I review the individually-driven runout tables, the situation has been somewhat analogous. In 1926 there were both a-c. and d-c. driven tables. Maintenance on the d-c. tables had been high; on the a-c. tables low. The cost of the d-c. drive was high, of the a-c. drive relatively low. A canvass of mill operators and mill builders revealed a unanimous preference for a-c. At that time the Ward Leonard or varying voltage system was suggested, but the economic factors appeared to be decidedly unfavorable. During recent years there have been many changes in the economic factors involved. There has been a very large increase in the power necessary for operation. This is not only due to the use of wider tables, but even more to the higher operating speeds and to the higher rates of acceleration and deceleration which are desired. If the economic balance is now in favor of d-c., this same situation has undoubtedly existed over the last five or six years. Many of the tables installed during that period exceeded in width some which are today being installed with d-c. drives. If this view is correct, it is regrettable that all we electrical engineers did not sooner recognize the desirability of reconsidering and re-evaluating the economic factors involved, for at no time has there been any question as to the successful operation of the long-used and oft-proven varying-voltage or Ward Leonard system. I am sure that Mr. Umansky is gratified, as I would be, to have drawn the attention of the steel industry to the desirability of such reconsideration and re-evaluation.

In a comparison of the two types of drives there are many factors to be carefully considered. In Mr. Hough's paper, published in the June issue of "STEEL", he presents in considerable detail such a comparison between a-c. and d-c. on a typical table consisting of 170 rollers. He evaluates the admitted power saving of the d-c. at about $4,000 when transferring, $5,600 when coiling, and $6,000 when piling. Mr. Umansky uses .7 of a cent per kilowatt hour, while Mr. Hough assumed .5 of a cent. While Mr. Umansky does not state the number of rollers nor the range of delivery speed of the mill, a complete analysis and comparison may show that their findings

are in substantial accord. Without having evaluated the additional cost of the primary motor-generator set supplying d-c. power to the whole mill, Mr. Hough concludes that there is an advantage in first cost of $42,500 favoring the a-c., while Mr. Umansky feels that the two types are quite competitive. I am sure that each of them is equally sincere, which is further evidence that a detailed analysis of a particular case is most desirable. The additional cost of the motor room for the larger number of a-c. sets can only be evaluated in co-operation with the company building the mill. Both agree that the cost of the motors alone is greater for d-c., while the cost of the motor-generator set is less. Mr. Umansky feels that the additional cost of the primary motor-generator set swings the balance in favor of the d-c., but does not give any exact figure.

Mr. Umansky states that a squirrel-cage motor will absorb in its rotor as much energy as the kinetic energy of the rotating masses at full speed. This is equally true of a d-c. motor if connected to a generator at full voltage and without external resistance in the armature circuit. If motors are gradually accelerated, in the case of a-c. through varying frequency, in the case of d-c. through varying voltage, the ratio between the developed torque and the accompanying kilowatt loss is much higher than when the a-c. motor is thrown on full frequency or the d-c. motor on full voltage. This is readily evident since torque varies directly with the current, while the loss varies as the square of the current.

In addition to the points mentioned by Mr. Umansky, a fundamental, theoretical advantage of the d-c. motor is the in-phase relation between the flux and the armature current; a condition which does not exist throughout the acceleration of an a-c motor. A further fundamental advantage is that the loss in the stationary winding is constant, while in an alternating-current motor the loss in the stationary winding varies much as the losses in the rotating winding, since the a-c. motor is essentially a transformer.

As Mr. Hough states in his paper, either a-c or d-c. drives will fulfill the requirement of adequately handling the steel delivered by the mill. To the a-c can be attributed the following definite advantages:

1. A more rugged and simple motor.
2. An absence of commutator and brushes.
3. Lower maintenance.
4. Lower WR^2 of the rotor.

The following advantages may definitely be assigned to d-c.:

1. Fewer sets and, therefore, less space in the motor room.
2. Lower conversion losses.
3. Dynamic braking by pump back throughout the whole range of motor speeds.
4. No field weakening of d-c. motors.
5. Simpler and less-expensive control.
6. Decrease in the capacity and size of the primary motor-generator set supplying d-c. power to the whole mill.
7. A controlled torque at the motor shaft, avoiding mechanical shock.

While it is not difficult to list the advantages and disadvantages of either system, it is much more difficult to properly evaluate and strike a final balance. As Mr. Umansky states, some tables will be driven by a-c. motors, some by d-c., the cost analysis will decide the issue in each specific case. For a considerable period it would appear desirable for the electrical manufacturer to prepare estimates of the first cost and operating cost for both a-c. and d-c. Under such a procedure the probability of an incorrect conclusion is materially reduced. All economic factors will be thoroughly studied, and there will be continued progress in their proper evaluation.

With the continued co-operation of the mill designer, the mill builder, and the mill user, the manufacturers of electrical equipment will undoubtedly present many ideas, both new and old, as to how the electrical equipment may be selected and applied to more effectively and economically contribute to the basic purpose for which such a mill is designed.

H. W. NEBLETT: Mr. Umansky's paper outlines an entirely new trend in the application of individual motor drives to the rollers of runout tables and coilers for wide strip mills. Until recently, the A.C. squirrel cage motor controlled by varied frequency was the accepted drive for this service. Our present 76″ Hot Strip Mill has A.C. motors driving the table rollers. The 44″ Hot Strip Mill referred to by Mr. Umansky is now being installed by us.

We have received commendable service from the equipment on our 76″ Hot Strip Mill using A.C. motors, but we are looking forward to the D.C. operation of the tables on our 44″ Hot Strip Mill with the expectation of securing better operating results.

One of the factors not mentioned by Mr. Umansky that we considered in the selection of D.C. motors is that in the case of A.C. motors controlled by variable frequency, the frequency cannot readily be varied over a range greater than, say, 15 cycles to 60 cycles. Whereas, with the D.C. drives using Ward-Leonard controls, smooth acceleration can be obtained from zero to full speed of the motor. This is of particular importance with present day hot strip mills due to the increase in the delivery speed.

Our 44″ Hot Strip Mill will operate at a delivery speed of approximately 1800 f.p.m. which is over twice the delivery speed of our present 76″ Hot Strip Mill. This calls for rapid acceleration and deceleration and care has to be exercised in a smooth functioning of the drive during these periods in order to prevent scratching of the steel strip. These factors plus those mentioned by Mr. Umansky were the reasons of our decision to install D.C. drives instead of A.C. Naturally, we cannot substantiate the operation of this equipment at the present time since our 44″ Hot Strip Mill is not yet complete.

However, we have been operating our 46″ Slabbing Mill for a period of approximately one year. This mill is equipped with Ward-Leonard controls for the entry and delivery D.C. table drives. In addition, the same control is applied to the screw-down, the manipulator, side guards and shear. The operation of this mill has proven to us the desirability of smooth

and rapid acceleration and deceleration accomplished with Ward-Leonard control.

J. FARRINGTON: Mr. Umansky has certainly given us a new and interesting thought on control for variable speed tables and coiler drives.

We have reached the condition where we are in need of a larger generator for our coilers and are seriously considering the installation of D.C. generators and motors using the Ward-Leonard control system, due to time and energy required to accelerate and decelerate the M-G set.

Due to our rolling time of a coil every thirty-five (35) seconds, we cannot consume more than fourteen (14) seconds in accelerating and decelerating the M-G set which becomes quite a problem in capacities of 200 KW and above.

We know the Ward-Leonard system of control is satisfactory as we have it on our Cold Mill drives.

The loss of power transformed into heat is fast becoming a serious item in the cost of production, and any system that will tend to reduce this heat loss is worthy of consideration.

In our opinion, the coiler motors should be of the water-tight, mill type design, provided they can be built of sufficient power and size to fit in the small space required, and operate on a maximum voltage of 300.

The generators should be designed to produce at least two hundred percent (200%) rated capacity in order to take care of the decelerating peak loads.

The mechanical parts should be designed heavier to stand the additional strain placed upon them due to field control steps.

This type of drive has one advantage that was not mentioned by the author; namely, that the speed of the pinch rolls and individual coiler rolls may be varied by a vernier rheostat in their respective fields in order to produce the same surface speed when the diameter of the rolls changes due to wear, as different surface speeds of rolls tend to scratch the steel.

I would like to ask Mr. Umansky how he could reduce the ratio of one M-G set per table section, where it is necessary to have each section faster than the preceding one unless a vernier resistance was used in each table roll motor.

I would also like to ask Mr. Umansky where this type of drive is in use, and how long.

L. A. UMANSKY: One of Mr. MacCutcheon's remarks might be readily misunderstood. He states that "in 1926 there were both a-c and d-c driven tables. Maintenance on the d-c tables had been high; on a-c tables low". As a matter of fact, in 1926 (and until 1937, for that matter) there were no runout tables with INDIVIDUALLY d-c driven rollers. The issue at that time was: Shall the runout table be group driven, through a line shaft or a belt by one or few relatively large motors, or shall the table drive consist of many small motors individually connected to the rollers. Since the adjustable speed was required then as it is now, the group drive naturally entailed the use of d-c motors operated from 230 volt supply. For individual roller drives squirrel cage motors were employed for reasons amply stated at the beginning of today's discussion.

Now, this "1926 issue" has been settled in favor of individual drive. The high maintenance expense of belts, or lineshafts, bevel gears, etc., has been the deciding factor, and not the maintenance on, say, 2–3 relatively large d-c motors, which are used by hundreds in steel mills.

With the individual type of drive having won the day, it was up to the electrical profession to offer a suitable motor. I am ready to repeat once more my statement that for the then prevailing conditions the use of squirrel cage motors with adjustable frequency supply was quite appropriate. However, it seems as if the electrical profession has been adhering to this system too long, possibly through the force of habit, even when the speed and capacity of the table drives grew by leaps and bounds with the development of the hot strip mills as we know them now. With the d-c system introduced on three latest strip mills we should be able to tell before long, with facts rather than mere opinions at our disposal, how the relative maintenance costs and operating characteristics of the two systems compare with each other.

It is undeniably true, as Mr. MacCutcheon states, that if a d-c motor is thrown at full voltage across the line and is allowed to accelerate, then there will be dissipated in its armature an amount of heat equivalent to the stored energy of the rotating masses connected to the motor. However, I do not believe that anyone has ever recommended this "simplified" type of control for d-c driven tables. Ward Leonard control or—in some isolated cases—magnetic control only are considered, whereby these armature losses do not exist. On the other hand, many a-c driven tables employ full voltage, full frequency starting, and likewise dynamic braking at full speed—rather than frequency control. This fact Mr. MacCutcheon undoubtedly knows quite well.

Another statement, also made by the same speaker, was to the effect that a squirrel cage motor has a lower WR^2 than a d-c motor, and that this constitutes an advantage for table drives. I disagree with this statement most definitely. For a start-stop service a d-c motor should have, and if properly designed usually has a lower WR^2 than a squirrel cage motor capable of performing an equivalent duty.

However, I will not press this point too hard against my opponent because the motor WR^2 may not be more than 5% of the total WR^2 to be accelerated by that motor, in case of a wide strip mill. Hence, the whole argument is of little importance.

I am quite sure that by the time of the next Convention we will hear from the operating men about their experience with the d-c system. This will answer many questions. No one is more anxious than I am to hear this answer.

Reading from left to right at the speaker's table are: H. G. R. Bennett, F. E. Leahy, R. B. Gerhardt, Lee Wilson, J. H. Graft, B. W. Norton, R. L. Leventry, L. F. Coffin, T. J. Ess, C. H. Carpenter, G. R. Carroll, J. Farrington, F. E. Flynn, C. H. Elliott, and Brent Wiley.

W. Graham, Superintendent 100" mill, Carnegie-Illinois el Corporation, Homestead, was among the day's guests.

ON March 21, the Cleveland district section of the Association sponsored a very successful inspection trip and meeting in Youngstown, Ohio. In the afternoon more than 400 members and guests visited the electric weld tube mills of the Republic Steel Corporation. R. L. Leventry, General Manager, Youngstown District, Republic Steel Corporation, deserves many thanks for the courtesies extended to the guests on the trip as well as for making arrangements to see that each one received a very beautifully printed brochure of the process. The entire personnel of the Rebublic plant cooperated in making the inspection trip successful.

In the evening a dinner was held in the ball room of the Ohio Hotel. This was followed by the presentation of a paper entitled "Radiant Tube Annealing Covers" prepared by C. H. Carpenter, Sales Manager, Lee Wilson Engineering Company. Instead of following the usual procedure for discussion of papers, the program committee had arranged in advance for seven prominent steel mill engineers to conduct a round table discussion from the front of the meeting room. Many favorable comments were heard regarding the discussion of a paper in this manner.

L. F. Coffin, President of the Association, spoke highly of Republic Steel Corporation's hospitality.

A. H. "Pop" Schwartz and Walter Greenwood, two of the oldest living members of the Association, enjoyed meeting old friends.

View of members and guests alighting from busses at the Republic plant.

COLD ROLL

By HOWARD W. KANE

Kane & Roach, Inc.

SYRACUSE, N. Y.

Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

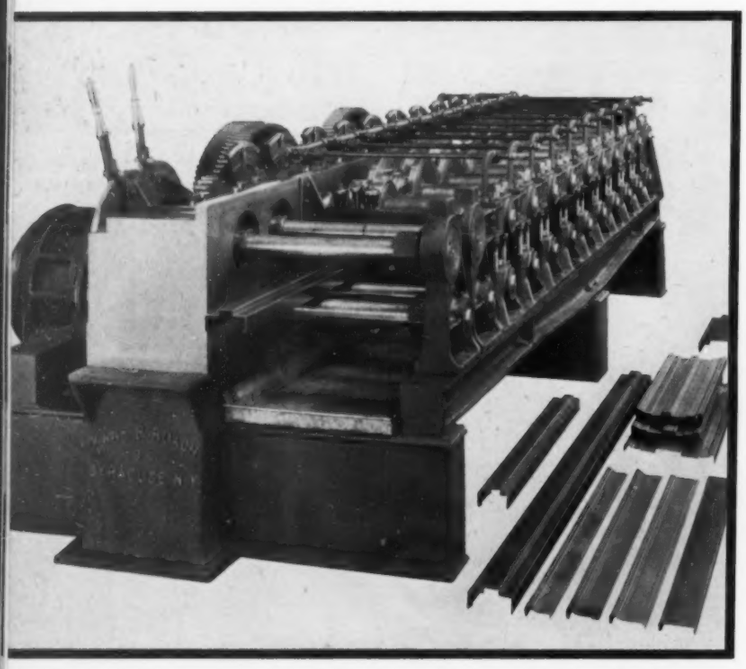
▲ ANY one who is in any kind of business today has to spend a great many hours thinking about the future possibilities of his particular business. If he didn't, he would probably wake up some fine morning to learn that the sheriff had been to the office ahead of him. So, it is not unnatural that I, too, have been doing some serious thinking for a long time back about the future possibilities for development in the particular industry in which I am interested, namely, the production of Cold Roll Forming Machines and other closely allied types.

As I have travelled about in various parts of the country, I have come in close personal contact with steel men and steel technicians and it has always been a pleasure to do business with them. I have received scores of valuable ideas from them and am grateful for the long range vision with which as a group they are likely to view any new problem. So, I feel, therefore, that it is an honor and a privilege to be called upon to address this distinguished assemblage tonight (or this afternoon). I make no claim for originality concerning the thoughts that I shall try to leave with you; many of you gentlemen here have undoubtedly been thinking along somewhat the same lines.

However, every man here has his own individual problem to consider first of all, and it may well be that some of you at least, have not visualized to the full the tremendous possibilities for cold roll forming of steel strip and how vitally the future of that business is tied up with your own. In brief, gentlemen, the cold roll forming industry is going places and I shall try, in the next few minutes, to present to you a panoramic view of the scenery along the way.

It is, of course, axiomatic that standard hot rolled structural shapes are the lowest in cost and it is rather probable that they will continue to be. However, it by no means follows that hot rolled sections are in every case the most desirable for the particular job under consideration. On the contrary, with the mounting demand for lighter weight sections from scores of industries, it is today possible to secure strength with lightness, either by ribbing or rolling a box section. Our problem, it frequently follows, is to turn out a section that is sufficiently light so that the saving in material justifies the additional expense of the rolling.

Cold roll forming machine of the outboard housing type for forming door frames and moulding sections.



I think that there can be little disagreement that the basic trend all along the line today is toward light weight construction. Steel houses, employing light weight construction throughout, have been in the public eye for a number of years now, but the time is not far distant when some one will make come true the mass production of prefabricated houses on a truly Ford scale. In fact, a recent issue of Life magazine devoted two pages of pictures of houses that can be erected and ready for occupancy within five days—houses that can be built for $4000 or $5000 and that are superior in most respects to the ordinary type of houses costing much more. And most significant of all to my way of thinking, these houses are conventional in appearance and will without doubt readily meet public acceptance. Cold roll forming is bound to play a big part in any such program, which has only now just started, but which within the next decade will, without a shadow of a doubt, reach gigantic proportions.

Within the last few years, also, the railroads have been making tremendous strides toward reducing the weight of their rolling stock. Modern, all-steel, high-speed trains of light weight construction are an accepted fact; they are cutting costs; they are making passenger traffic profitable once more; they are fitting themselves into the modern picture. The amount of equipment that the railroads will buy in the next ten

Forming of STRIP STEEL

HOWARD W. KANE

years is actually colossal. And here, too, the cold roll forming industry will certainly play a conspicuous part, for light weight sections for interior trim in passenger coaches will be mandatory.

Wherever transportation enters, light weight is all-important, which accounts for the pronounced tendency toward reduction in weight in truck and bus bodies through the use of lighter weight steels. Here again the cold roll forming industry has been playing an important, if inconspicuous role. No picture of future transportation methods would be complete without giving thought to airplanes, which for years back have employed duralumin and other light weight metals in their construction. With all the genius and adaptability that the steel industry commands, I feel sure that it is only a question of a short time before all-steel construction of airplanes will be a common place. In fact, a recent advertisement in "Time" showed seaplanes of all steel construction. Light weight sections, steel construction, and cold roll forming are a trinity that already have gone far and which will go much farther.

Another great advantage to be had with the cold rolled section is that of closer tolerances. The mills set liberal tolerances on their hot rolled sections and it is not practical for them to do otherwise. The Cold Roll Forming Machine, on the other hand, because of its flexibility of adjustment, is able to roll to close tolerances with ease.

To touch on another phase, I think most of you will agree that the hot roll mills are geared only to quantity production, or to requirements that fit in with quantity production. In order to get a hot rolled section, you have to accept standard mill sections, or your volume of production must be sufficient to justify the initial cost for the special rolls required to produce the section. In the ramification of products which are being built today, there is practically no end to the number of shapes and designs which must be manufactured, either through press, hot rolling, cold roll forming, drawing, extruding, or by some other method of forming a shape to get the particular design desired for the individual product. It is right here, therefore, that the cold roll forming industry can come to your aid, for it offers you a means of forming a great many sections which because of price, quantity or peculiar shape, do not lend themselves to forming by other methods.

We are all familiar with the purchasing agent who, when asked when he must have delivery, replies that he should have had the material yesterday. No one, of course, can do the impossible, but it is true that where time counts greatly, cold roll forming speeds up the picture remarkably. A set of rolls for the average structural shape can be turned out in a comparatively short time, facilitating quickness of delivery. Moreover, the cold roll forming of strip steel leaves you many sources of supply, so that you are not tied down to any particular mill or warehouse, and the strip—either in the sheet or in the coil—can be stocked and slit and used as required. Finally, the rolls are quickly interchangeable on a Cold Roll formming Machine. If a section is to be made for which rolls are readily available, the rolls can quickly be

Cold roll forming machine of the outboard housing type for rolling roof deck sections.

changed over from one section to another without appreciable loss of time.

Among other advantages of cold roll forming that might be mentioned are high production speed, low initial tooling and machine cost, low unit rolling cost, saving in floor space, low operating cost due to lessened power consumption, and the fact that a section can be completely formed in one pass. The ever changing models in every field of industry today are pointing the way to almost limitless possibilities for the further development of cold roll forming, which is so quickly adaptable to changing requirements.

No doubt you gentlemen are fully aware of the time-saving possibilities that cold roll forming permits. I wonder if it is generally known that it is not only possible to run a piece out of a forming machine to whatever length desired, but also to cut the piece, bend or coil it, punch it, paint it, solder it, tin it, plate it, braze another coil on—all in one continuous operation.

Further, cold roll forming makes easily possible a smooth, high finish of the product.

Looking to tomorrow, to next year, to ten years hence, what will be the trend, which way will fabricators of steel be headed? I think the answer is plain, for the steel industry today is, one might almost say, a new industry. New from the point of view of new concepts, new objectives, which in turn necessitates new methods of thinking, new ways of doing things. The metallurgical laboratories of the steel mills are busy places these days. Plenty of midnight oil is being burnt by these modern magicians in the laboratories, magicians who are daily transforming the world around us.

I spoke a few moments ago about the coming demand for pre-fabricated steel houses. We in the cold roll forming industry are looking forward to this development with no mere academic interest, for these new light-weight, low-cost steel houses are going to give a tremendous impetus to cold roll forming, as well as to the thousands of fabricators large and small who will find that method the ideal one for the rapid production of countless sections. Just to name a few that come quickly to mind, I might mention box columns, box beams, electric conduit pipes, studding, door bucks, framing, metal trim, rafters and ridges, conductor and down-spout pipe and gutters. It will take time to get these parts standardized, but standardization will come and with it low costs all along the line, including even such intangibles as fire insurance for dwellings, for these new houses will be virtually fire-proof.

And as the use of metal trim for dwelling becomes more and more commonplace, one does not need to be especially good at prophecy to visualize what is going to happen to the merchant marine and to passenger carrying ocean vessels. The memory of the burning of the Morro Castle off Atlantic City with its tragic loss of lives is so recent that it is stamped indelibly into our memories. I myself happened to witness the burning of the Bermuda at the dock at Hamilton. The list of such fires is long, much too long. And such fires are not going to continue indefinitely. Something is going to be done about it—and that something is the substitution of steel for wood in ship construction. Fancy wood carving and paneling may be all right in a millionaire's library, but it has no place on an ocean-going vessel, where the question of safety is paramount at all times. The graining and staining of steel for interior trim is already an accepted fact and there will be further developments along this line. Light-weight sections will, of course, be fire-proof, but more than that, they are going to be decorative as well. Finally, there is going to be mighty little furniture of any kind on the ship of the future that is not going to be made of steel. There isn't going to be anything to burn.

Speaking of furniture, witness what has been happening in porch and office furniture. Everywhere you go, you see modernistic steel furniture, strong, practicable, comfortable, fire-proof and vermin proof, and built for a lifetime of service. I am by no means sure that the present vogue of modernistic styling in furniture is here to stay; it may be or it may not be. But of one thing I am sure, and that is that light-weight steel furniture is only in its swaddling clothes. All of which means, in due time, tremendously increased volume for the steel mills. And it means, equally certain, a tremendous amount of cold roll forming.

Most of you men take frequent train trips. One of my earliest recollections and one of my greatest boyhood thrills was a trip by train. A three hundred mile ride was a real event. The thing that gave me the biggest kick of all and fascinated me the most were the advertising signs on the unpainted wooden barns. There were no radios in those days, and there was comparatively little advertising in magazines and newspapers. Advertising was something to be pasted on billboards and painted on barns. There wasn't a barn along a railroad right of way in the country that didn't have sprawled all over it "use Sapolio",

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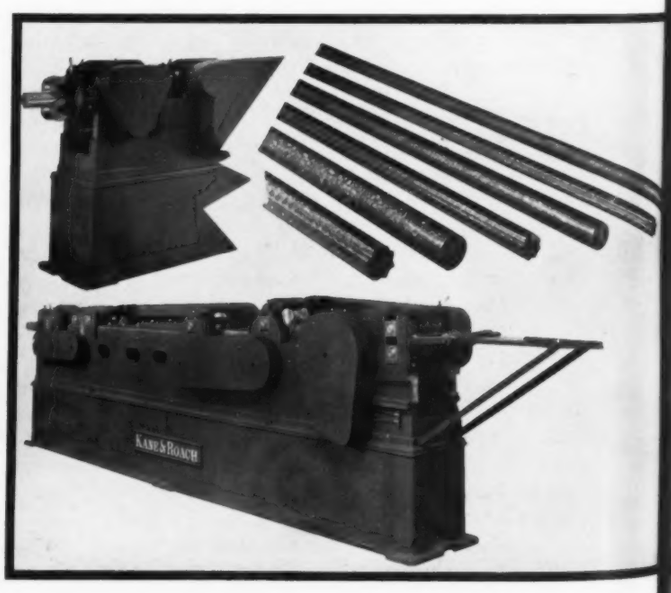
Special cold roll forming machine for rolling down-spout plain round and round corrugated. These machines are also made to produce square corrugated downspout and gutters.



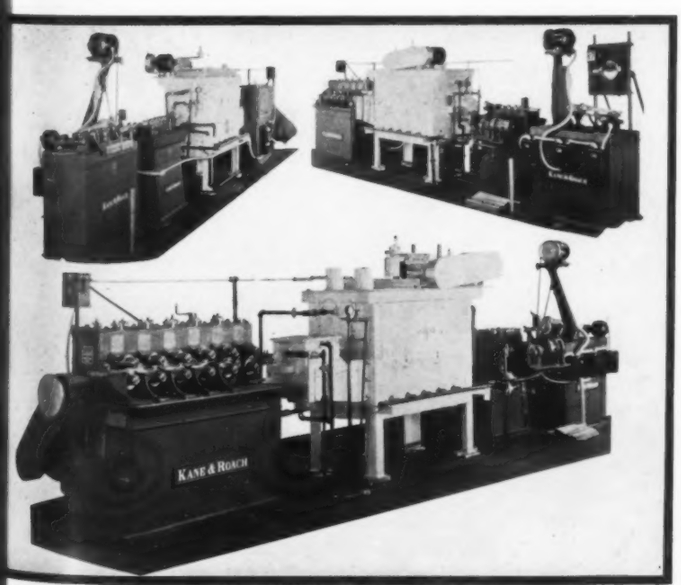
"Smoke Bull Durham", "Castoria, Babies Cry For It", and of course, "Smith Brothers Cough Drops" and the pictures of the two famous old gentlemen with their dignified whiskers.

Advertising has changed, like so many things and the advertising men don't use barns very much these days to exploit their wares. They have found better ways. But the funny part of it is that the kid of today who takes a train trip sees the same old wooden barns or barns that look just the same. That is, except for the lack of advertisements on them. They certainly are still made of wood. And that alone ought to be enough to constitute a challenge to any good steel man—or any man, who like myself is closely associated with the steel industry. Why should they be made of wood? What's so good about wood? It has to be painted frequently if it isn't going to fall apart.

Here's one that the steel industry is going to change. I can't give you the exact day or hour. But one of these days, the kid who takes his train ride is going to be looking at steel barns. They're going to be put up in four or five days without any erecting machinery, because they're going to be made of light-weight structural sections, roof and all. And they're going to be fire-proof. Flying showers of cinders from trains aren't going to set fire to these barns and they're going to be properly insulated, against the possibility of spontaneous combustion. They are going to be inexpensive, too, once the sections become standardized and turned out in large volume. This is going to give the steel mills more tonnage, and our industry is rooting hard along this side line for these happy days to arrive. There is no reason under the sun why silos and every other building on the farm including, if you will, the late Chic Sales' useful little building of classic design, shouldn't be made of steel. And you can bet your old age pension they will be.

Gentlemen, you've all heard about the boy who was busily engaged pounding his thumb with a small hammer. A man came along and said to him, "What in the hell are you hitting your thumb for with that hammer?" And the boy replied, "Because it feels so good when I stop". And, that's about the way I feel now. And I think you fellows have been patient in bearing with me thus far. In closing, I have but one final thought, and I mean this most sincerely. You men are doing important jobs, every one of you. You are a part of one of the most important, if not *the* most important industry in the world today. The steel industry is truly the mother of industries. It sets the pace for countless other industries. It is something, in a man's life to be a part of all this, to contribute something, even a very tiny something, to progress and development, and I know that we in the cold roll forming industry have been stimulated by your achievements, have been spurred on by your endeavors, and that we shall try as best we can to keep step with you.

Cold roll forming machine, tinning machine, straightening machine and rotary cut-off machine. This machine will form, trim, straighten and cut to length automobile radiator tubes.



DISCUSSION

PRESENTED BY

R. M. HUGHES, Asst. Chief Engineer, Great Lakes Steel Corp., Ecorse, Michigan

H. P. MUNGER, Metallurgist, Republic Steel Corp., Warren, Ohio

R. S. SHOEMAKER, Representing Works Management, American Rolling Mill Company, Middletown, Ohio

C. M. YODER, President, Yoder Company, Cleveland, Ohio

R. M. HUGHES: I first wish to take the opportunity of stating how pleased I am to discuss the paper that Mr. Kane, whom I have known for a number of years, has so capably prepared and delivered. It shows the broad understanding that Mr. Kane has of the subject with which he is dealing.

I also wish to thank Mr. Brent Wiley, Managing Director of the Association of Iron and Steel Engineers, for the invitation to discuss Mr. Kane's paper.

The subject of the paper is broad, and considerable time could be spent in discussing a paper of this character. However, I only wish to take a few minutes to elaborate on some of the points which Mr. Kane mentioned.

We, in the Steel Industry, are naturally interested in the use of steel and are particularly interested in the development of new uses for strip steel. In the past three years there has been a considerable increase in the strip-producing capacity of the Country, and it follows that new uses for the material must be developed if all of these mills are to be kept operating at full capacity.

Regarding the question of steel homes, the Stran-Steel Division of the Great Lakes Steel Corporation fabricates steel lumber. This steel lumber is suitable for the rough framing of homes, barns, construction buildings, in fact any type of building that requires lumber for framing. At the present time this company does not manufacture homes known as "prefabricated houses", but their products are suitable for the building of a conventional home as we know it today, or building the new modernized home similar to the prefabricated homes.

This material is designed so that carpenters or semi-skilled workers without any special training can lay it up and erect it in the job just as they build with lumber. The balance of the building materials that go into homes, such as shiplap, Celotex, Sheetrock, and lumber, are nailed directly to the steel framework. The steel is so fabricated that the nails can be driven in and hold securely in place any materials that are nailed to it, and it takes a considerable pull to remove the nails when driven in place.

When you stop and consider the use of such material and the features that it adds to a home, it stands to reason that the public are naturally going to be interested in the use of this class of material. It lends itself readily to the use of concrete floors, and, if concrete floors are not desired, the conventional wood floor can be used. The rooms can be divided up in similar manner to any of the homes of today, and the roof framing can be made to suit the individual's taste. In other words, if you desired an early American plan of home, a farm type home, or a modern flat roof building, these all can be built up from this steel lumber.

This lumber is usually made from 16 ga. hot strip steel and is formed in machines similar to those about which Mr. Kane speaks.

This is just one of the many items which are manufactured today, made possible by cold forming machines. There are hundreds of other items being manufactured and producing an outlet for strip steel similar to steel lumber, and no doubt in years to come hundreds of other new uses will develop for steel similar to those mentioned.

I thank you, gentlemen, for your kind attention.

H. P. MUNGER: The author has painted a picture of the future uses of cold roll formed shapes in many places where structural shapes or other sections are used at present. We are entirely in accord with the idea that light weight sections will be designed in which the metal is used to its best advantage for the fabrication of furniture, building and transportation facilities.

So far as the steel industry is concerned, it has been our policy to produce a product to fit the needs of the fabricator. The automotive industry will bear witness of the increasingly difficult draws which steel is being called on to make in forming parts for the modern automobile—and the quality of the steel which has been improved to keep pace with the demands of these die makers.

In the same way fabricators, including the cold roll forming industry, have sought a material with a higher strength-weight ratio. In reply to this demand, low cost, low alloy steel were developed, such as Republic Double Strength, USS Corten, Youngstown Yoloy and a host of others, to meet this demand.

It is apparent to all fabricators and users of steel that the steel industry stands ready to develop a tailor-made steel for the cold roll forming manufacturers, and for other manufacturers as soon as there is an economic justification for such a development.

R. S. SHOEMAKER: Mr. Kane's paper, which so ably describes the future possibilities of cold rolled forming machines, has been extremely interesting.

We, as steel men, are bound to welcome any increased outlet for the vast tonnage of flat rolled steel and alloys being produced today. We all, I think, are conscious of the very decided trend toward lightness and strength in all lines of manufacturing. In recent years, we have seen, formed, stamped, and built up welded parts rapidly replacing the heavier forgings and castings previously used. As these changes have been brought about, the designing engineer has had in mind the reduction in weight, reduced cost, and increased strength of the machine or structure.

Our modern mill machinery and electrical apparatus is an outstanding example of how far this trend has progressed. Little detailed information seems to be available about these cold roll forming machines or the product to come from them. However, it is not too unreasonable to assume that in the near future the designer will be able to pick up his new hand book of cold rolled structural shapes and choose the steel or alloy sections best suited to his immediate requirements. When this is an accomplished fact, then the steel house, the stream lined train, and the fireproofing of ocean shipping will have been given a very decided impetus toward volume or assembly line production.

In closing, I want to re-emphasize what ,as I see it, is the high light of this paper: namely, that there is a most decided trend toward light weight construction in practically all lines of engineering—and this to my mind should spell reduced costs. The possibility of reduced costs to the ultimate consumer in this country has always lead to volume production and in this case volume production of the major items sighted by the author will mean increased tonnages for the steel companies.

C. M. YODER: I am greatly honored for the privilege of coming before you to discuss the merits of this important subject, and especially so after listening to the well thought out paper so ably given by our friend, Mr. Kane.

I may not agree with him on all of his deductions, but am sure we do agree on the great fundamental principles of the art of Cold Roll Forming, and of its tremendous importance to the Steel Industry, at present, as well as in the future.

The cold roll forming of metal into so-called structural shapes and special shapes used in connection with railroad rolling stock and other similar equipment, as well as shapes for light building construction, is one of the most talked of subjects of the steel industry.

I contend that this cold roll forming of structural shapes not only produces a smoother surface, but also allows the engineer to design the shape to procure

the strongest and at the same time, the lightest weight member possible.

I cannot concur with a statement in the paper previously presented, namely, quote

> "It is of course axiomatic that standard hot-rolled structural shapes are the lowest in cost, and it is rather probable that they will continue to be" unquote.

I wish to present to you some figures and cost data to prove that cold roll formed structural shapes are now being made much cheaper than hot rolled sections, and, in the future, will continue to be made at a very much lower cost. This applies to the cost of equipment, as well as the cost of production.

With the continuous strip mill completely finishing strip steel to 100 inches in width, at the rate of approximately 2,000 ft. per minute, multiple slitting this stock into the desired widths, and recoiling same up to 500 ft. per minute; then forming this metal into the required shapes at the rate of 100 ft. to 300 ft. per minute, depending upon the complexity of the shape, thickness of stock, and alloyed content of the steel.

Another important advantage of the cold forming method is that the flat strip may be treated to prevent corrosion, either by galvanizing, or by one of many other treatments. This treating of the metal in the flat state before forming is accomplished more conveniently and much cheaper than treating the section after it is formed, while in hot rolled sections they must be pickled and so treated in the finished shape.

Cold roll forming mills are now in production with combination sets of rolls for forming Z bars and similar sections from steel varying in thickness from 20 gauge to $\frac{3}{8}$" webs from 2" to 8", and any variation of flange length *on the same set of rolls* and machine. Similar variations may be made on angles, channels, and in fact, on the so-called standard or more commonly used sections.

Combination built up sets of rolls may be rearranged on the mill to form the same section in the size variation mentioned. By adding additional rolls, the final shape produced may be modified. This construction saves setup time and reduces first cost.

I do not recommend however, that stock as light as 20 gauge be formed in large production on a machine large enough to form $\frac{3}{8}$" thick stock. I only present this great variation to show how universal, and in what a wide range of sizes and thicknesses the cold forming of metal will accommodate.

Data from several plants show that the cost of forming metal from 14 gauge to $\frac{3}{16}$" in thickness and from approximately 4" to 15" in width, average around $5.00 per ton, cold roll formed and straightened, ready for shipment, with all strains relieved, so that they will remain straight after shipment.

While on the other hand, the hot rolled sections of similar size and weight will cost $5.00 to $7.00 per ton for straightening only. It is interesting to note that the straightening of hot rolled sections does not relieve all of the strains, causing many sections to be rejected because of their crookedness after shipping. In the manufacture of a wide variation of sizes and shapes for railroad cars and similar work, cold roll formed and straightened from mild steel $\frac{1}{16}$" to $\frac{3}{16}$" in thickness, in lengths of 20 feet or more, at a speed of less than 100 ft. per minute, the production was 700 to 1,000 lbs. per man, per hour. Please note that the production given above was at a very low rate of speed.

The speed of this class of forming on presentday equipment can easily be doubled, thereby proportionally reducing the cost still further.

In the forming of several hundred tons of one size of structural shapes, the cost has been as low as $3.00 per ton.

On an average, cold roll forming and straightening will cost no more than the straightening only of hot rolled shapes.

The art of hot rolled shapes has had many years of development, and is now at its height of perfection, while the cold rolling is in its infancy. As the art of cold roll forming is being developed, and larger production is obtained, the cost will be even more favorable.

It is not only in this Country that the principle of cold roll forming of metal shapes is taking a very prominent position in the minds of most steel men, but also in England and on the Continent.

In July of this year, I personally inspected an apartment house and a 75,000 ft. factory building in London, England, that was built of fabricated cold formed steel. The heaviest metal used in the factory building was $\frac{1}{8}$" in thickness, and that in only a small portion. Practically the entire building was fabricated from 20 to 26 gauge steel. The Bays of this building are 60 feet wide by 30 ft. cross.

There are sections developed for floors and walls and fabricated from steel 22 to 26 gauge. The wall section will contain only from $1\frac{1}{2}$ to 2 lbs. of steel per sq. ft., while the floor section carrying a live load of 150 lbs. per sq. ft. on 14'–0" span, contains only about 3 lbs. of steel per sq. ft.

These fabricated sections are so designed that floors of various depths, spans, and floor loads may be made from standard unit cold formed sections. The sections are also made for walls of various thicknesses. These units are not only designed for factory and other large buildings, but are particularly adapted for light low cost home construction as well.

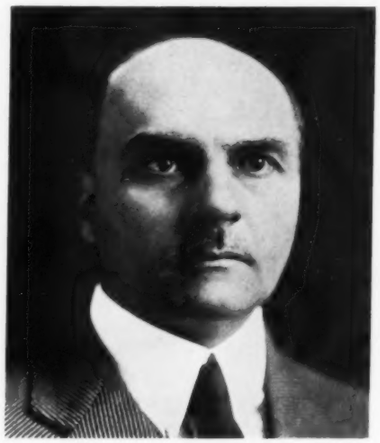
Gentlemen,—owing to the limited time allotted me today, I can give only a brief summary of the available data concerning the cold roll forming, but is it not sufficient to convince the most conservative man, that it is not necessary to wait and look to the future for the development of the art of cold roll forming of metals.

It is here now, in everyday practice and production in all types of work and construction.

Are you ready in your own line of industry for this newer development, to take full advantage of every saving it affords, and be out in front, leading your competitors with the latest design and up-to-date products you manufacture?

Every man connected with steel, whether he be an Engineer, Executive, or in the Mill on production, not only owes it to himself, but also to the Company that employs him, to make a complete study into every detail of the cold roll forming and working of sheet and strip metal; ascertaining its advantages, to determine where the savings will be the greater, using this method in your particular Industry.

SURGES



H. WEICHSEL

▲ IN order to insure the continuity of electric service which is so necessary to our industrial life, we must protect the transformers, contributing to that service, from lightning and the transient voltages which may be produced by switching operations or arcing grounds. The purpose of this paper, is to discuss briefly the means available for protecting transformers from these abnormal voltages.

If a transmission line is subjected to a voltage materially in excess of its normal operating voltage the weakest member connected to it gives away. If, for instance, the insulators on a transmission line cannot withstand as high a voltage as the transformer connected to the line, then the insulators will spill over when excessive voltages occur. If, however, the insulators have a higher insulating level than the transformers which are connected to the line, the latter must withstand the abnormal voltage. In order to restrict the voltages which may occur on a distribution or transmission line to a reasonable low level, it is standard practice to connect lightning arresters or similar protective equipment to the line.

In order to fully understand the action of lightning arresters, the engineer must be able to subject these devices to artificial lightning which can be created at will, and he has therefore developed equipment by which artificial lightning can be produced and recorded. Surge generators produce the artificial lightning and cathode ray oscillographs record the results of its application to insulators, transformers, etc. Auxiliary devices are used for the measurement of voltage and for the synchronization of the impulse voltage with the power frequency voltage wave, but a discussion of the equipment and technique used in making these tests is entirely outside the scope of this paper. However, photographs of the equipment in use by the writer's company are shown in the following figures: Figure 1, Figure 2, Figure 3.

The wave shape of the artificial lightning can be controlled, and the A.I.E.E. has standardized upon wave shapes to be used when testing certain types of equipment. The wave shape is defined by the use of

FIGURE 1

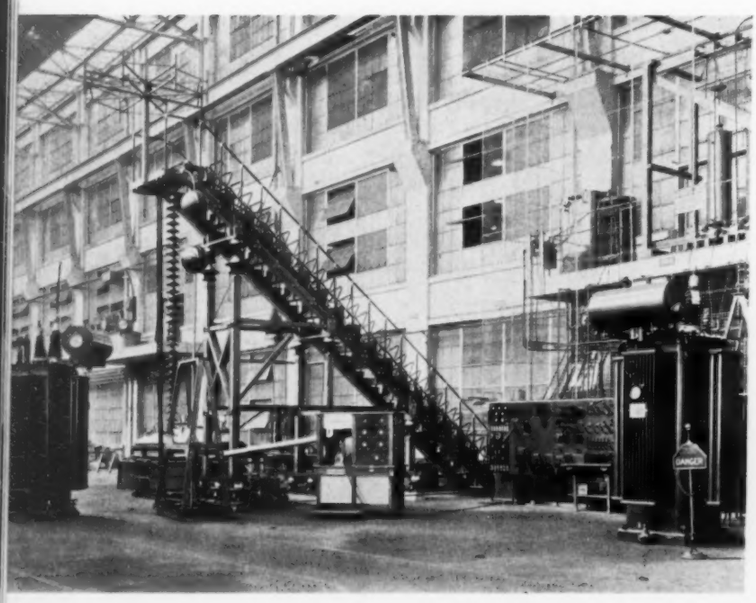
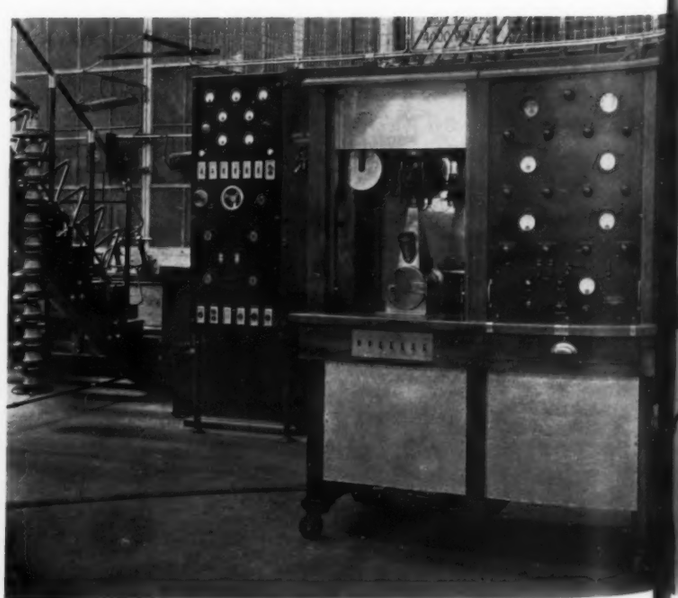


FIGURE 2



GES and THEIR EFFECT on TRANSFORMERS

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two figures, the first of which is the number of micro-seconds required by the wave to reach its crest, and the second is the number of micro-seconds required for the wave to decay to one-half its crest value. (A micro-second is one-millionth of a second.) The wave in which the manufacturer and user of transformers is most interested, is one which rises from zero to a maximum value in 1½ micro-seconds, and which decays to half value in 40 micro-seconds after the initiating of the wave, and is known as a 1½–40 wave. Throughout this discussion a 1½–40 wave will be assumed unless otherwise stated.

Tests carried on with equipment of this nature have yielded very interesting results. For instance, if a spark gap, of the rod gap type, is subjected to a 1-10 wave and an oscillogram is taken of the wave, it will be found that for a given gap setting a voltage wave with a relatively low peak value cannot breakdown the gap. The wave develops into its full strength as shown in curve 1 of Figure 4.

If the voltage is gradually raised a value will be reached at which the gap breaks through, curve 2. The cathode ray oscillogram shows that a breakdown of the gap did not occur at the time at which the voltage had its maximum, but occurred long after the wave has passed its peak value. The breakdown occurred "on the tail of the wave" as indicated by the curve 2. The breakdown of the gap manifests itself by a sudden break in the voltage curve. If the voltage is adjusted for still higher values without, however, changing the wave shape, then breakdown occurs nearer to the peak of the wave as shown by curve 3. Finally, a voltage value may be obtained where the breakdown occurs at the peak of the wave as shown by curve 5. If the voltage is still further raised the breakdown occurs on the front of the wave as shown in curve 6. The tested breakdown points can be connected by a curve as shown in the dotted line. This curve is sometimes referred to as the "time lag curve". Generally, however, if the engineer speaks of a time lag curve he refers to a curve obtained from the breakdown points just

FIGURE 3

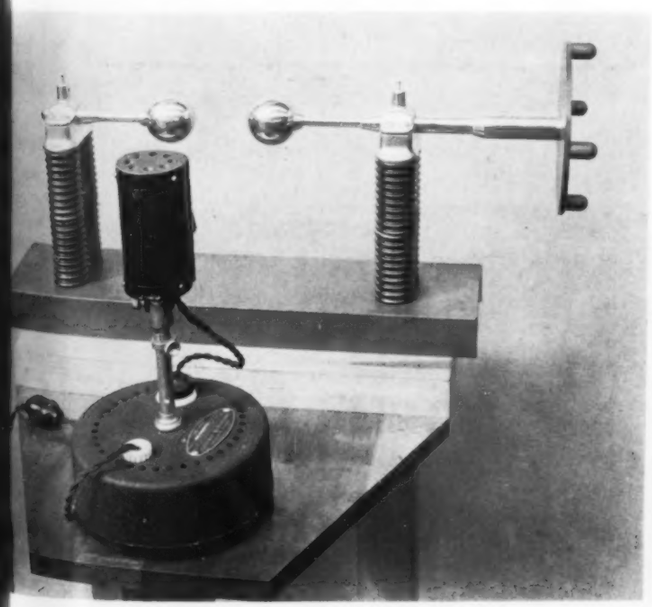
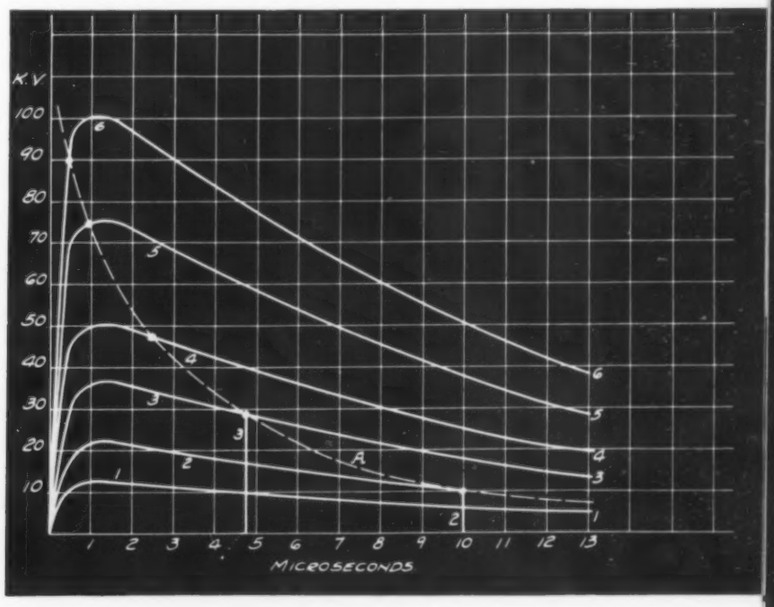


FIGURE 4



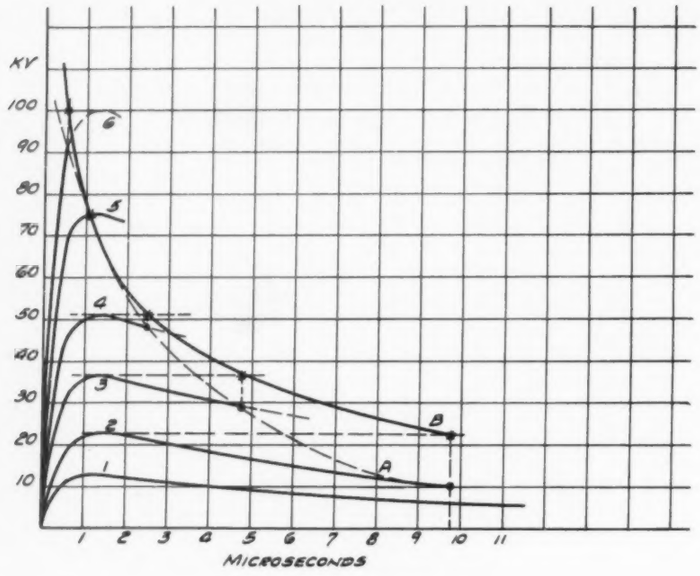


FIGURE 5

discussed but plotted in a somewhat different manner. The peak voltage is plotted as a function of the time at which breakdown occurs, diagrammatically shown in Figute 5.

This curve is to be interpreted as follows: When a 1½–40 wave with a certain peak voltage is applied to a particular gap, a breakdown of the gap occurs as many micro-seconds after the application of the voltage as indicated by this curve. The *peak* volue of the voltage wave corresponds to the ordinate of this curve. The breakdown actually occurred, however, at a lower voltage than indicated by this curve. In other words, the curve on Figute 4 represents the voltage value at which the breakdown occurred and curve B on Figure 5 represents the peak value of the voltage wave which was used for creating the breakdown.

The simplest way to protect electrical equipment against over voltage is to connect a spark gap between the line and ground, and adjust the length of the gap so that it requires a breakdown voltage which is less than the voltage which the transformer can withstand. The above discussion explains the action of such gaps when subjected to high voltage surges. Instead of connecting the spark gaps on the outside of the transformer to be protected, it was proposed by Mr. Kline in the year 1921 to make the gap a part of the transformer bushing. Reproduction of the Kline arrangement is shown in Figure 8.

Later in the paper it will be shown that some of these gap arrangements do not have the desirable characteristics, of preventing a power frequency follow current when the gap, is spilled over by a high voltage charge on the line. The power frequency current which flows through the gap, after it has been fired byt he high voltage discharge, is frequently called the "follow current" or "dynamic current".

One of the earliest devices for interrupting the power follow current is the horn gap arrester which has been in use over 40 years. Figure 9 shows this arrester in its simplest form.

After the gap has been bridged by the high voltage discharge, the dynamic current follows and forms an arc. Due to heat action as well as magnetic action the arc is forced upwards, and the length of the arc is increased until it is interrupted. It takes several cycles before the dynamic current is interrupted, as it requires some time for the arc to travel upward.

Another type of device which has the characteristic of interrupting the follow current and which has been marketed during the last few years is, in principle, a spark gap surrounded by a material which has the property of giving off gases when a heavy current passes through the gap. These gases quench, within a fraction of a cycle, any power current which may attempt to follow. There are several devices on the market which suppress the follow current by this gas quenching

FIGURE 6

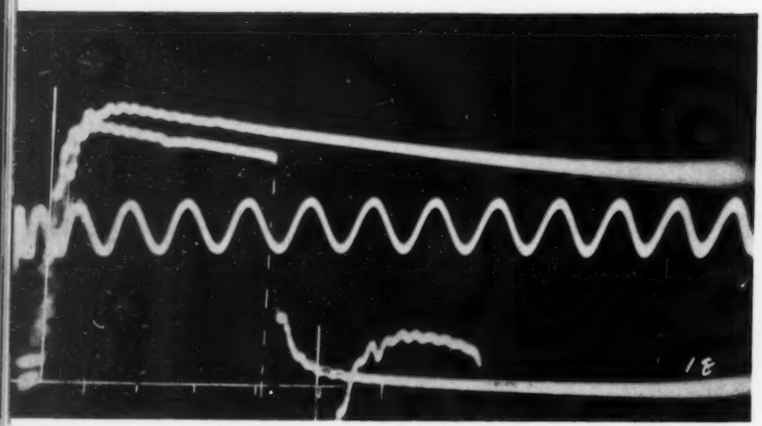
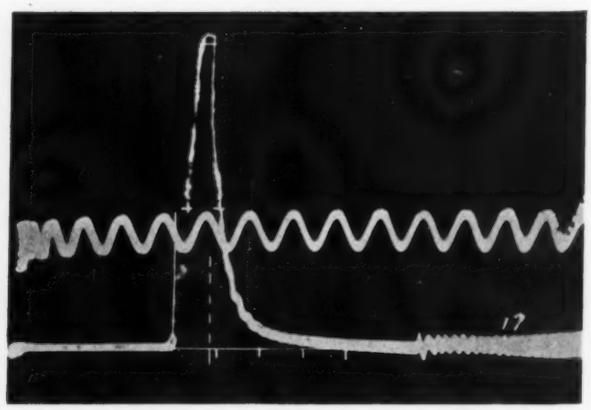


FIGURE 7



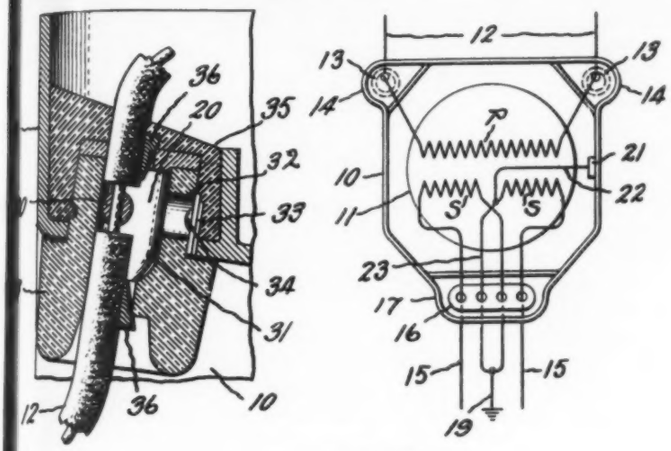


FIGURE 8

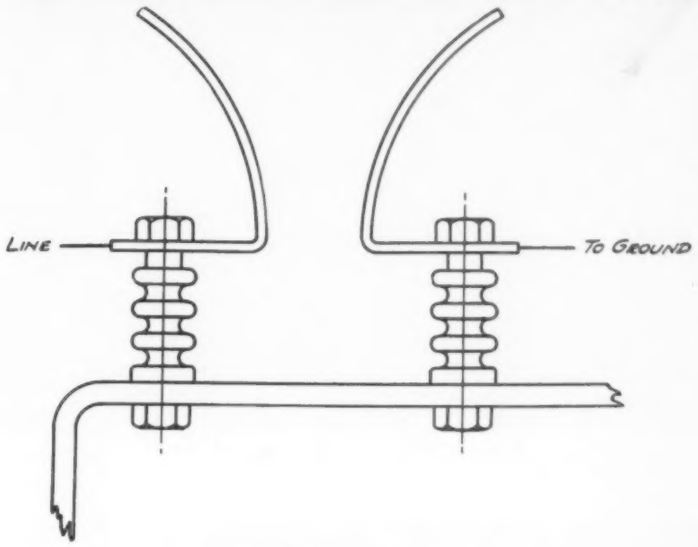


FIGURE 9

action, and they differ only in their mechanical construction. Figure 10 gives a cross section of a spark gap making use of the quenching action of a gas.

Valve type arresters also have the ability of preventing follow current. They are marketed by a number of concerns. Figure 11 shows a cross section of an arrester of this type.

The main parts of the valve type arrester are a number of small spark gaps and a column of a crystalline material which has the peculiarity of having a low resistance when subjected to high voltages and a very high resistance when subjected to low voltages. In other words, it has ideal quenching characteristics. The crystalline material withstands tremendous temperatures without changing its structure.

Now let us study briefly the behavior of the different

FIGURE 10

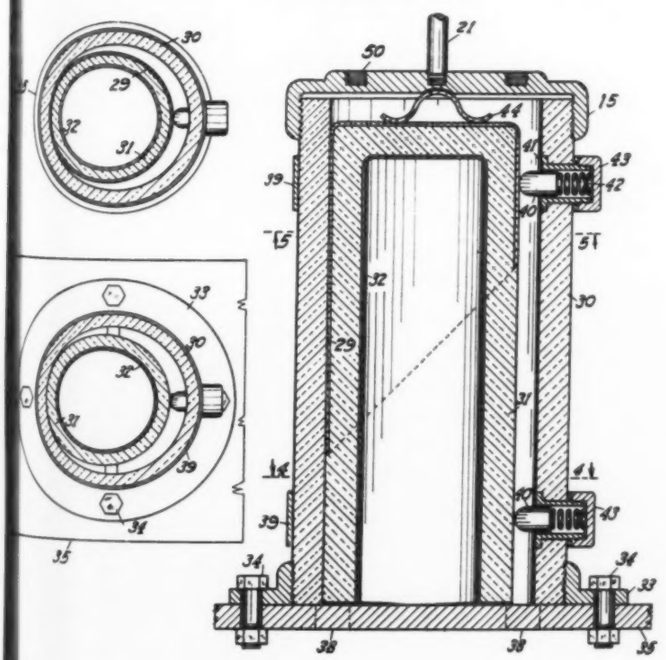
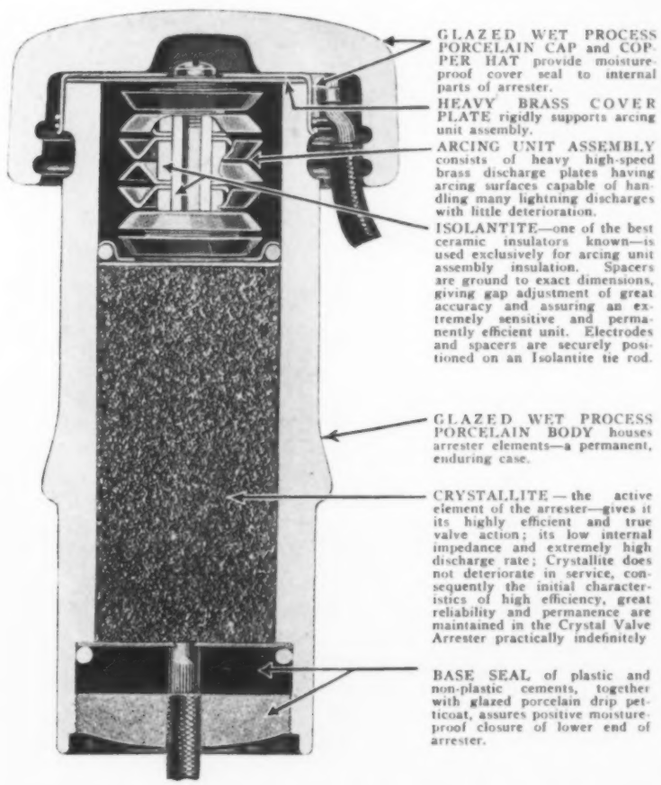


FIGURE 11


GLAZED WET PROCESS PORCELAIN CAP and COPPER HAT provide moisture-proof cover seal to internal parts of arrester.
HEAVY BRASS COVER PLATE rigidly supports arcing unit assembly.
ARCING UNIT ASSEMBLY consists of heavy high-speed brass discharge plates having arcing surfaces capable of handling many lightning discharges with little deterioration.
ISOLANTITE—one of the best ceramic insulators known—is used exclusively for arcing unit assembly insulation. Spacers are ground to exact dimensions, giving gap adjustment of great accuracy and assuring an extremely sensitive and permanently efficient unit. Electrodes and spacers are securely positioned on an Isolantite tie rod.
GLAZED WET PROCESS PORCELAIN BODY houses arrester elements—a permanent, enduring case.
CRYSTALLITE — the active element of the arrester—gives it its highly efficient and true valve action; its low internal impedance and extremely high discharge rate; Crystallite does not deteriorate in service, consequently the initial characteristics of high efficiency, great reliability and permanence are maintained in the Crystal Valve Arrester practically indefinitely
BASE SEAL of plastic and non-plastic cements, together with glazed porcelain drip petticoat, assures positive moisture-proof closure of lower end of arrester.

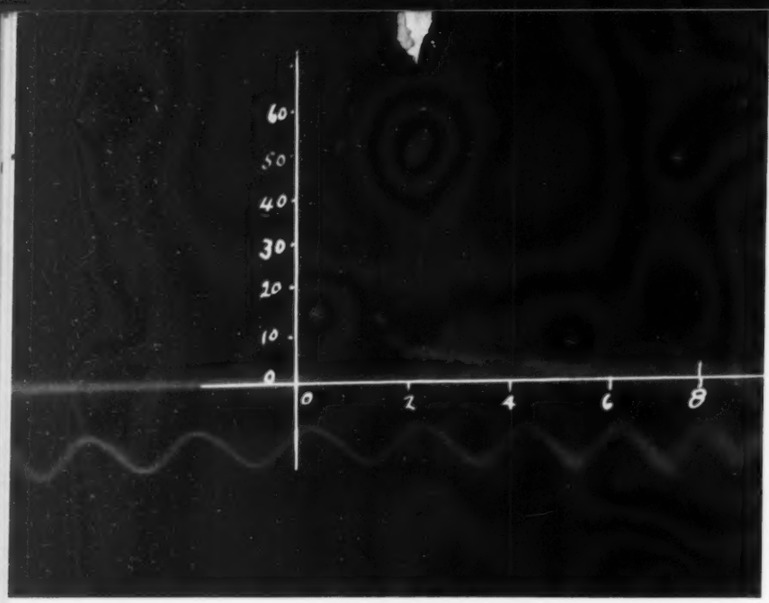


FIGURE 12

It will be noticed that the voltage reaches a predetermined value, then suddenly breaks down the gap in the lightning arrester, and thereafter, the voltage drops materially but does not drop to zero. Thereupon, it increases to a maximum and gradually dies out.

If a test wave with a large current is selected, then the so-called impedance voltage of the arrester reaches higher values as shown in the upper curve of Figure 13. An actual oscillogram is shown in Figure 14.

The larger the current discharge the higher is the so-called impedance voltage. If the maximum voltage which appears across the arrester is plotted as a function of the maximum current Figure 15 is obtained.

This curve is plotted from a large number of tests carried out in our surge laboratory. This figure is a curve for a 2400 volt arrester and shows that the voltage across the arrester is in the neighborhood of 14 or 15 kv.

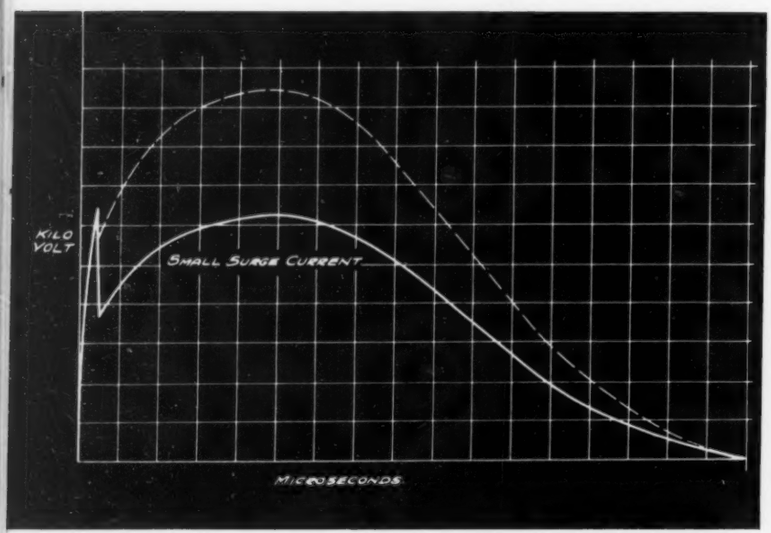


FIGURE 13

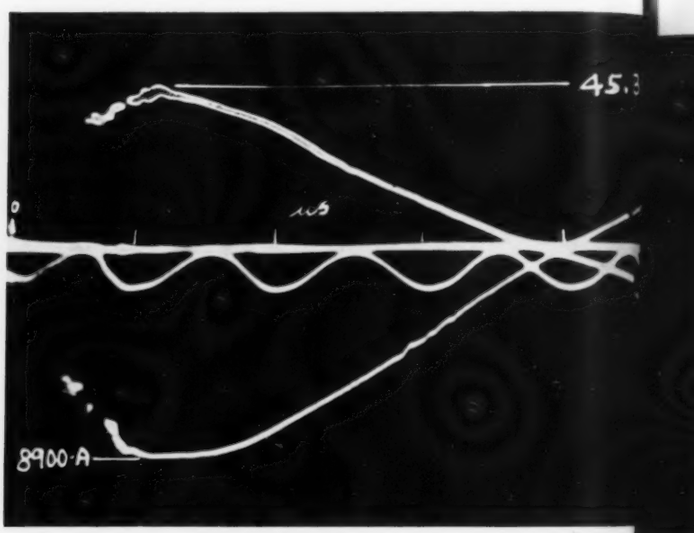


FIGURE 14

protective devices just described. The behavior of a simple open spark gap when subjected to a high voltage surge has been discussed previously. If the gap is surrounded by a material which gives off gas we have a "gas quenching gap". The behavior of a gap of the gas quenching type is very similar to that of a standard gap when subjected to a high voltage surge, that is, if the surge voltage wave is adjusted for a sufficiently high peak value, it rises to a certain value depending on the design of the gap and immediately after falls off to zero. Gaps of the gas quenching type used in connection with 2400 volt, 60 cycle circuits have the characteristic of reaching a value of 50,000 to 55,000 volts, then suddenly breaking down and reducing the voltage to practically zero. See Figure 12.

Oscillograph tests of valve type arresters show somewhat different characteristics. Figure 13 shows the behavior of a valve type lightning arrester subjected to a voltage wave which carries a relatively small current.

as long as the discharge current does not exceed 2000 amperes. For discharge currents larger than 2000 amperes the voltage gradually increases but even at 10,000 amperes the voltage across the arrester has only reached approximately 40,000 volts. This diagram also shows the voltage across a gap of the gas quenching type. This gap has the characteristic of requiring about 55 kv. for breaking down and this voltage is practically independent of the discharge current. From this figure it is clearly seen that a transformer protected with a lightning arrester of the valve type is considerably more fortunate than a transformer protected by an arrester of the gas quenching type. In the latter case all surges of 55,000 volts or less strike the transformer with full strength, just the same as if the transformer were not protected at all. If the transformer is equipped with a lightning arrester of the valve type, the voltages which strike the transformer have values considerably less than 55 kv. as can be seen from this figure.

The figures shown so far clearly demonstrate the discharge characteristics of the different lightning protective mechanisms used today on transmission lines. However, they refer only to the voltage discharge phenomena which take place when the transmission or feeder line to which these protective devices are connected is not energized by normal power frequency.

The following studies deal with the phenomena which take place when the transmission line is energized at normal frequency and is subjected to a surge. It is self-evident that the surge may strike the line at any point of the power voltage wave. For instance, the surge may strike the line when the power voltage wave has its peak value or when it is zero or any value between these limits. Consequently, arrangements must be made in the laboratory to simulate these conditions.

It is clear that the power voltage cannot send any follow current through either an arrester or a spark gap if the surge strikes the line at the moment when the power frequency voltage is zero. On the other hand, if the surge strikes the line when the power voltage is at its peak a follow current is very apt to occur, because the surge ionizes the path through which the high voltage surge spark has traveled, and thereby turns this path into a conductor. Consequently, the power current may follow. Tests we have carried out show that 60 cycle follow current on a 2400 volt circuit and a 2" rod gap takes place about 70% of the time. During the remaining 30%, a follow current may occur or may not occur, depending upon when the surge strikes the 60 cycle wave, substantially as shown in Figure 16.

During this test the circuit to ground contained approximately 10 ohms resistance. This clearly demonstrates that follow currents do not necessarily occur every time a surge breaks down a gap or spills over an insulator. Further tests have been made in our laboratory which demonstrate that the probability of a follow current depends on the resistance in the circuit with the gap. For a given gap there appears to be a critical series resistance, which when exceeded, prevents follow current at any point of the 60 cycle wave.

Previously in the paper reference was made to the gap proposed by Mr. Kline. One side of the gap is connected to the tank of the transformer, which in turn is connected to ground, and the other side of the gap is connected to the 2400 volt line. We have subjected a "Kline gap" to surge voltages and follow current tests. It was found that this type of gap has self-quenching features when the resistance in series with it is 180 ohms or more. Fig 17 shows the oscillogram of a quenched 60 cycle current which flows through the Kline gap, when the resistance in series therewith is 500 ohms. These tests explain why the Kline gap functioned satisfactorily in some installations while in others it frequently gave serious trouble due to follow current. In the former case the ground resistance was probably high while in the latter case it was probably low.

By enclosing a spark gap with a gas producing

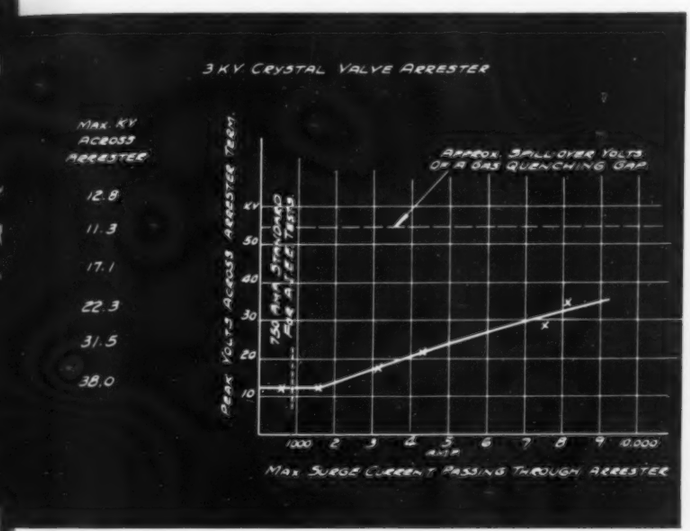


FIGURE 15

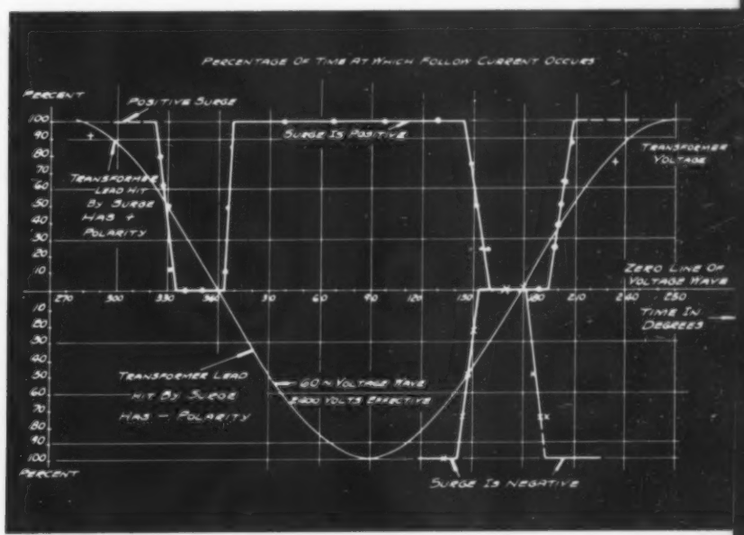
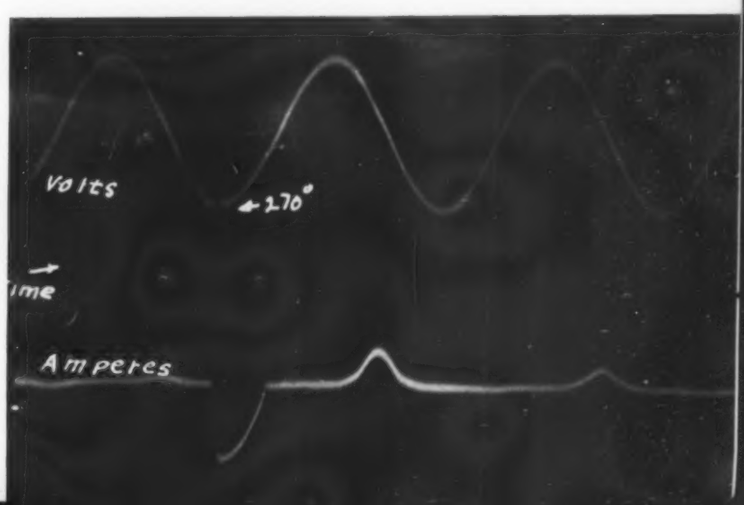

Percentage Of Time At Which Follow Current Occurs
Percent
Positive Surge
Surge Is Positive
Transformer Lead Hit By Surge Has + Polarity
Transformer Voltage
Zero Line Of Voltage Wave
Time In Degrees
270 300 330 360 30 60 90 120 150 180 210 240 270
Transformer Lead Hit By Surge Has − Polarity
60 ~ Voltage Wave
2300 Volts Effective
Surge Is Negative
Percent

FIGURE 16

FIGURE 17



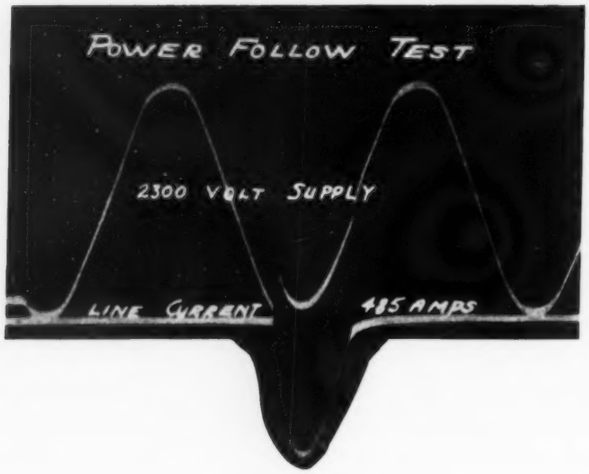


FIGURE 18

material it is possible to quench the follow current even if the series resistance is practically nil. This is the gap we have previously called a gas quenching gap. The gases which are produced by the passage of the arc in turn quench the arc. Oscillograms made on this type of gap show that a follow current takes place when the surge strikes a line which is energized, but this follow current only lasts until the power voltage wave passes through zero. In other words, if the surge strikes just after the wave has passed through its zero value, the follow current will continue until the power voltage has reached its next zero point. For the condition just cited the follow current lasts approximately 1/120 of a second. The follow current during this time may reach very appreciable values as it is limited only by the impedance in the circuit between line and ground which may be extremely low, and consequently the follow current may be very high. If, for instance, the resistance in this circuit is 5 ohms and the circuit is such that full line voltage occurs between line and ground, then a current of $\frac{2400 \times \sqrt{2}}{5} = 680$ amperes flows from line to ground. An oscillogram published by one of the makers of this type of gap is shown on Figure 18.

The follow current in this case reached 485 amperes and lasted for an appreciable part of one half cycle.

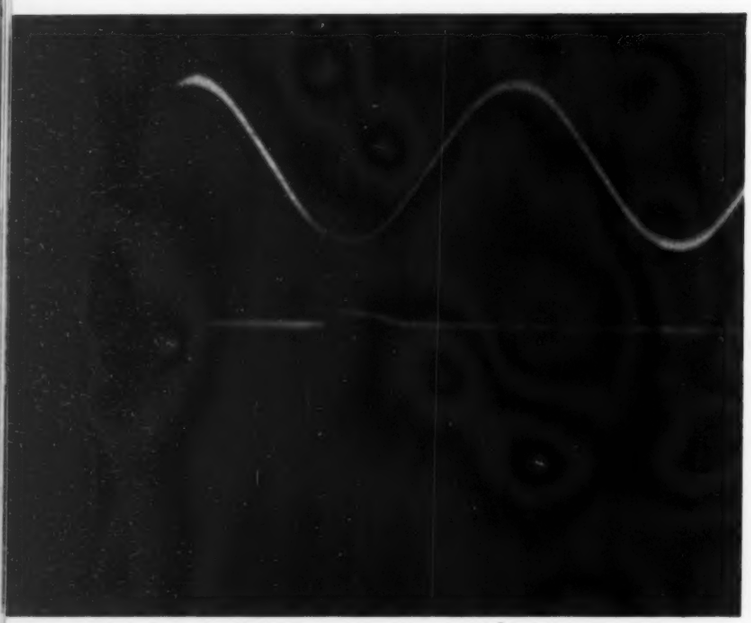
In a valve type arrester the follow current is extremely small or zero, no matter at what time the power wave is struck. Figure 19 shows the absence of a follow current in a valve type arrester whose gap is broken down by a surge.

The transformer with which this valve type arrester was tested had a rating corresponding to that of the arrester. It will be seen that a current of very short duration is recorded on the oscillogram and that this is the surge current with which the circuit was hit, but no noticeable follow current occurred in spite of the fact that the surge was so adjusted that it occurred at a time when the power wave was near its maximum.

A few words of explanation may be in order as to why no follow current occurs. The so-called impedance element of the arrester, which as stated before consists of a pile of crystals, has a very peculiar characteristic. If current is sent through this pile of crystals and the voltage across this pile is plotted as a function of the current passing through the crystal pile, a curve is obtained somewhat as shown in Figure 20.

With 2400 volts across the pile, the current is practically zero. On the other hand, the current corresponding to a voltage of 13,000 volts across the crystal pile is very appreciable. The other curve in this figure shows the resistance of the crystal pile as a function of the current. This curve is easily derived from the volt-ampere characteristic just mentioned. The resistance current curve shows that the resistance is practically infinite for small current values. Consequently, it is impossible for much follow current to flow because the normal line voltage is not sufficiently high to produce any appreciable current through the pile of crystals.

FIGURE 19



The characteristics of the two most frequently used types of protectors have now been shown in a general way. The next important item is the method of connecting these arresters to the transformer or other apparatus to be protected. The oldest connection is shown in Figure 21.

The arrester is connected directly between the line and the ground. Let us assume that the surge which hits the circuit carries 1000 amperes. If the arrester is of the valve type, then a voltage of approximately 15 kv. appears across the terminals of the arrester as explained previously. For our discussion the resistance from arrester to ground will be assumed to be 20 ohms. Consequently, the 1000 amperes flowing through this resistance create 20,000 volts across the end of arrester and the real ground point. The total voltage between line and the real ground point is therefore 20 + 15 = 35 kv. and it appears between the high voltage winding

of the transformer and the low voltage winding of the transformer, if the low voltage side of the transformer is grounded as is usually the case. In other words, the insulating barrier between the high voltage winding and ground is subjected to a voltage of 35 kv. if the surge carries 2000 amperes instead of 1000 amperes the arrester voltage hardly changes and remains approximately 15 kv. while the drop across the ground wire increases to 2000 x 20 = 40 kv. Consequently, a voltage of 55 kv. occurs across the insulating barrier of the transformer. It will be seen from this that the higher the ground resistance the higher the voltage across the barrier of the transformer. Consequently, the transformer is more endangered the higher the ground resistance of the arrester. It may be stated therefore that *the voltage across the insulating barrier in a transformer increases with the surge current and with the ground resistance.*

The current of the surge is determined by dividing the surge voltage, by the so-called surge impedance of the line. This surge impedance is practically a constant figure regardless of the length of the line, and amounts to about 500 ohms. If the surge voltage is 1,000,000 volts, then the surge current is $\frac{1,000,000}{500} = 2000$ amperes. This current must pass from the wire to the ground and its value is more or less independent of the resistance between the transmission line and the ground. In other words, the surge current is mainly determined by the surge impedance of the line. In reality, conditions are not quite as simple as explained, but this explanation may be sufficient to show why it is allowable, in discussing the behavior of arresters, to assume a given current flow.

In the early days of the electric power industry, not much attention was paid to ground resistance and frequently very high ground resistances were found. Consequently, high voltages appeared across the insulating barrier of the transformers, and it is no wonder that the failures on the transformers were relatively high due to surges on the line. This condition was exaggerated by the fact that frequently the arresters were not mounted close to the terminals of the transformer but were quite a distance away, an arrangement which is very unsatisfactory.

An electric surge wave travels along a transmission line in much the same manner as a water wave travels over the surface of a body of water. When the water wave strikes a solid wall it is well known that it rises to practically twice its natural height. When an electric wave travels along a wire and finally reaches the open end of the wire it behaves like a water wave reaching a wall. Consequently, if a surge strikes a line and then travels along the line to the nearest lightning arrester, its value will be reduced or limited to let us say 15 kv. After the wave has passed the arrester and has thereby been reduced in its height, it may continue to travel until it reaches the point where it doubles in value and reaches 30 kv. It is therefore readily seen that the danger of breaking down a transformer is greatly increased when the lightning arrester is mounted away from the transformer instead of close to the transformer. (See Creighton A.I.E.E. 1912, P. 820, Paragraph No. 1). Experience has shown that actual breakdowns on transformers are reduced about 65%

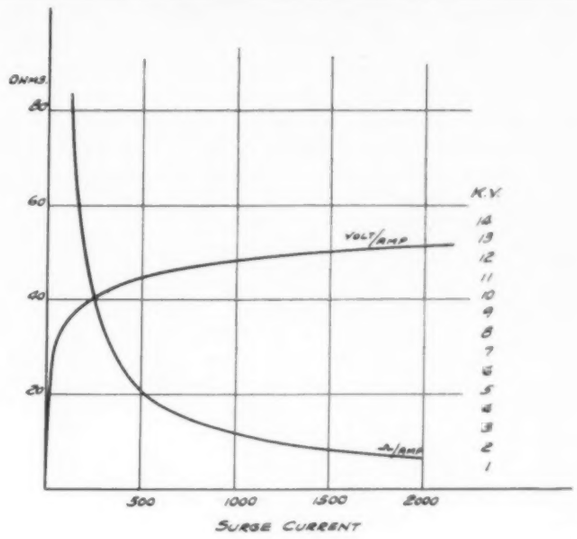
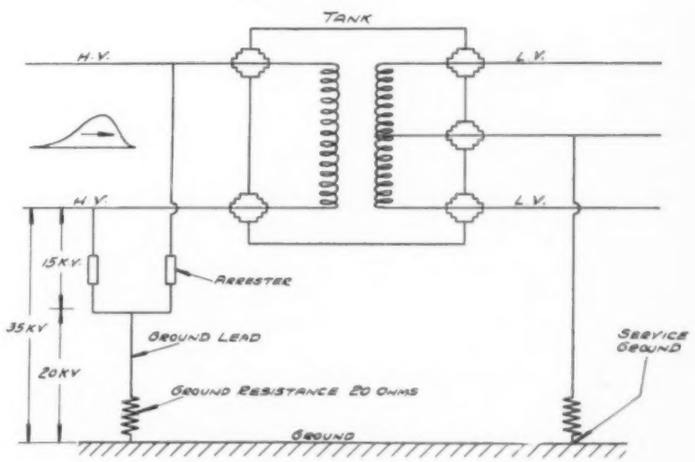


FIGURE 20

when the lightning arresters are connected close to the transformers. This was known as far back as 1914, see A.I.E.E. page 702.

Reducing ground resistances and locating arresters close to the terminals or transformers, have both contributed materially to a reduction in transformer failures caused by surges. But engineers were not content with this progress. They realized that the ground resistance materially affects the voltage which can appear across the transformer insulating barriers. As far back as 1912 Mr. Creighton published in the A.I.E.E. certain connections between lightning arrester and transformers which are in use today. It was he who pointed out for the first time, (to the writer's knowledge), the advantages which can be obtained, by what is called today, interconnection. That is,

FIGURE 21



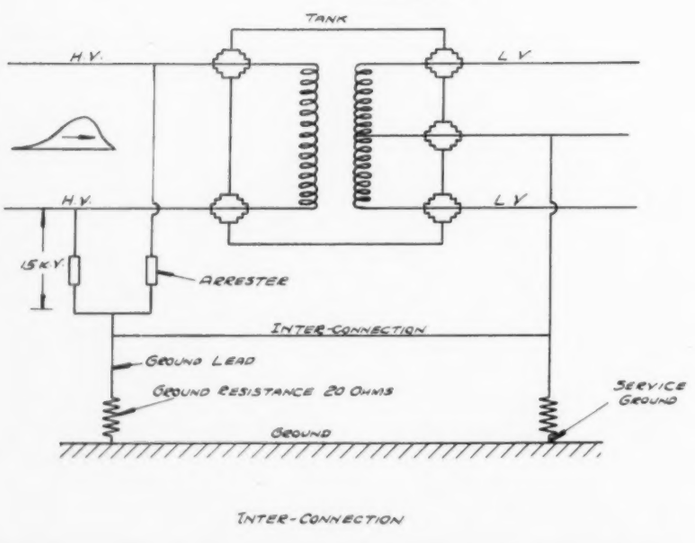
CONVENTIONAL SYSTEM
WITHOUT INTER-CONNECTION

the high voltage side and the low voltage side of a transformer are interconnected by placing an arrester between the two. Besides this connection Mr. Creighton mentioned a number of other connections which all accomplish practically the same result. Some of the connections he described connect the tank to the interconnecting member. Strange to say it was many years before the value of Mr. Creighton's suggestions were fully appreciated.

At about the same time Mr. Roper of the Commonwealth Edison Company made a very careful study of the different items which were responsible for the breakdown of a large number of transformers. He published his findings in the A.I.E.E. Proceedings of 1914. As a consequence of these investigations the Utilities Research Commission sponsored a very elaborate series of tests at Purdue University to determine the advantages and disadvantages of the different connections between lightning arresters and transformers. These tests clearly showed that the so-called inter-connection was extremely promising. Encouraged by these test results the Commonwealth Edison Company placed a large number of transformers in service with this connection. In the Electrical World dated December 13, 1933, Mr. Roper reported the success of this connection as follows:

"The first year of operation of 5,700 distribution transformers with secondary neutrals connected to the lightning arrester grounds shows a 65 per cent reduction in percentage of transformer troubles due to lightning. The effect of this interconnection is to reduce the magnitude of the transient voltage across and between the parts of transformer and thus decrease the chances of arcs over porcelain bushings and across air spaces, which are the principal causes of fuse blowing. When the results from different types of arresters are compared it is found that the smallest percentage of fuses blown corresponds to those types of arresters which limit the transient voltage to the lowest value.

FIGURE 22



INTER-CONNECTION

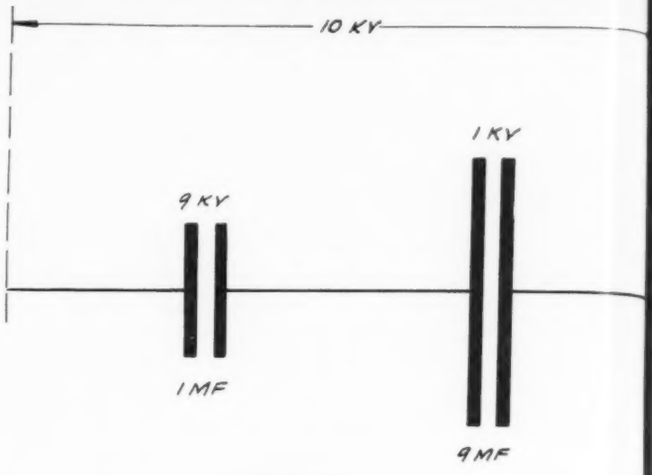


FIGURE 23

The 5,700 distribution transformers which were reconnected as recommended in the 1932 A.I.E.E. paper of Harding and Sprague have now been in service about a year. During that time failures have been:

Burning of primary leads	3
Failure of insulation between primary and secondary	4
Failure between primary turns	1
Total	8

It is to be noted that the failure record of these 5,700 interconnected installations is about one-seventh of 1 per cent and, further, that the age of the transformers that failed ranged from nine to thirty years with an average of nineteen. This appears to indicate that with modern-type transformers, built to withstand a transient voltage test, the present scheme of lightning protection in Chicago would be practically perfect."

It behooves us to stop for a moment to analyze the reasons why this interconnection has proven so successful in protecting transformers against lightning and surges. The connection in its simplest form is shown by Figure 22.

It will be noticed that the highest voltage which can occur across the insulating barrier of a transformer is the voltage which appears across the terminals of the arrester. For a 2400 volt transformer this voltage is in the neighborhood of 15 kv. in case a valve type arrester is used and is about 55 kv. in case a gap of gas quenching type is used.

It is also of interest to determine the voltage which appears across the high voltage terminals and tank. This voltage tries to spill over the high voltage bushing of the transformer. The voltage which appears across the tank and the low voltage circuit is also of interest. This latter voltage tries to spill over the low voltage bushing.

In order to solve this problem let us study first a combination of two capacitors (condensers) connected in series. If a surge strikes such a combination it will

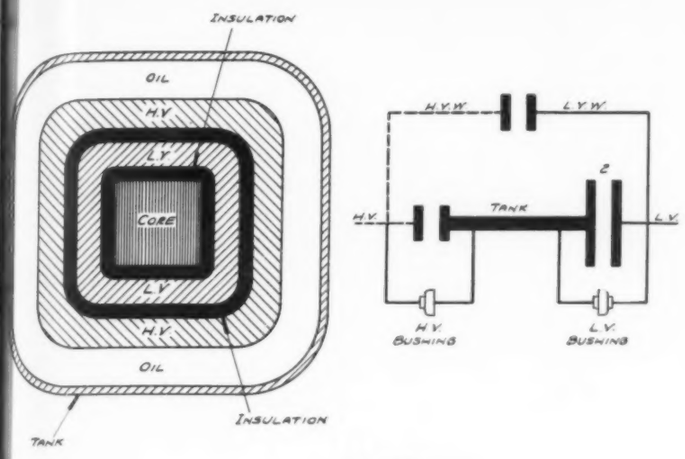


FIGURE 24

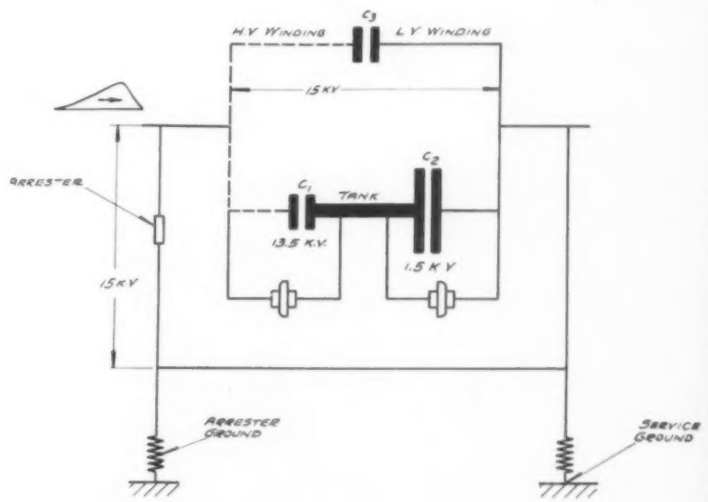
be found that the voltages across the condensers are inversely proportional to the magnitude of the capacities. In other words, if two capacitors of 9 mf and 1 mf are connected in series and a surge strikes this combination, then the voltage across the 1 mf capacity is 9 times the voltage across the 9 mf capacity, that is, the voltages divide in the ratio of 9 to 1, the higher voltage appearing across the smaller capacity. This is shown in Figure 23.

A capacitor is made up of two conducting members separated by an insulating medium. In a transformer there is a capacity action between the high voltage winding and the low voltage winding. The windings are equivalent to the conducting members of a capacitor and the insulating medium separating these two conducting members is the barrier or insulation between the high voltage and low voltage. Evidently, there is also a capacity action between the high voltage winding and the tank. This capacity is partly due to the high voltage winding forming one of the conducting members, and the oil separating them forming the insulating medium of a condenser. The high voltage bushing also contributes to the capacity action between the high voltage winding and tank because the high voltage lead forms one conducting member and the tank the other conducting member, while the porcelain bushing is the insulation which separates the conducting members. In identically the same manner a capacity effect exists between the tank and the low voltage winding. Tests have shown that the ratio of these capacities is 9 to 1, in 2400 volt distribution transformers. The higher capacity exists between the low voltage winding and tank. A little thought shows that the capacity between the high voltage and low voltage winding, the capacity between the high voltage winding and tank, and the capacity between low voltage winding and tank are electrically connected as shown in Figure 24.

Figure 25 shows a schematic circuit of a lightning arrester applied to a transformer by means of the so called interconnection. The transformer with its internal capacities is diagrammatically represented in the manner outlined on the previous figure. Earlier in this paper it was pointed out that for this interconnection the surge voltage across the barrier (high voltage to low voltage winding) is equal to the voltage which appears across the lightning arrester. For sake of argument let it be assumed that a valve type arrester is employed and therefore 15 kv. appears across the high voltage and low voltage winding. This voltage divides in the ratio of 9 to 1, that is, 13.5 kv. appears across the high voltage winding and tank and 1.5 kv. appears across the low voltage winding and tank. These are the voltages which try to spill over the bushings of the transformer. A study of this diagram further shows that the voltage across the transformer is absolutely independent of the ground resistance.

After determining how the surge voltage distributes across the different main parts of a transformer, it is a relatively simple matter to select insulation and bushings of correct breakdown strength. Naturally, the bushings must be selected so that they spill over at definite voltage values which must be in excess of those voltages which can be expected from the above reasoning. The Company with which the writer is connected prefers to use, for this reason, so called stud type bushings. This type of bushing offers the advantage of a definite spill over voltage. The high voltage bushings are so selected that they spill over at approximately 65 kv. for a 2400 volt transformer. The maximum voltage which can be reasonably expected across the high voltage bushing is about 15 kv. if a lightning arrester and interconnection is used. Therefore, a large factor of safety exists between the spill over voltage of the bushing and the voltage to which this bushing should be subjected. The major transformer insulation is naturally so designed as to stand a voltage higher than the surge voltage which can appear across this barrier. This grading of the

FIGURE 25



different insulation levels is generally known as "co-ordination of insulation". While the so called co-ordination of insulation has come to the front more conspicuously during the last few years it must be remembered that it is not a new principle but was realized many years ago. For instance, Mr. Creighton in his paper of 1912 states: (A.I.E.E. Volume XXXI, paragraph 1, page 818.)

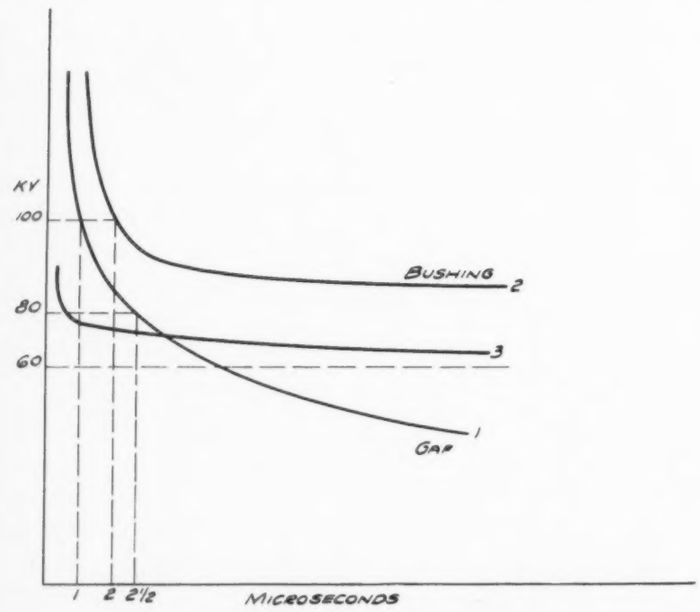
> "There is always a limited spark potential around the bushing on the transformer and it is only necessary to make this spark potential somewhat lower than the spark potential between primary and secondary in order to minimize the dangers of even a direct stroke".

In order to grasp the full meaning of the coordination of insulation it is necessary to remember the time lag curves discussed in the beginning of this paper. It was shown that the breakdown of a spark gap occurs a certain length of time, after a surge voltage of a predescribed wave shape and peak voltage has been applied. This time delay is shorter the higher the .peak of the impressed voltage wave.

Exactly the same phenomenon appears on bushing and insulating materials. However, different bushings and different insulating materials may have, and frequently do have, different time delay characteristics. Let it be assumed that a rod gap, that is an open type gap, is used for protecting a transformer. The time lag curve for the gap is represented by curve 1, Figure 26. The time lag curve of the transformer bushing is represented by curve 2. If a 1½–40 wave strikes this assembly the rod gap spills over before the bushing fails. In other words, the gap protects the bushing.

This can be seen from Figure 26 as follows: If a

FIGURE 26



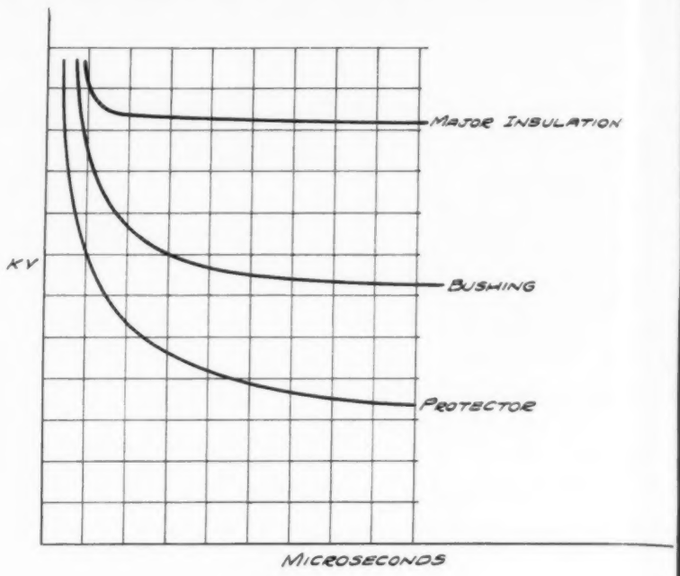


FIGURE 27

1½–40 wave with 100 kv. peak value strikes the assembly, the gap breaks down in one microsecond and thereby lowers the surge voltage to a very low value, provided the gap is suitably grounded. Consequently, the surge voltage which remains after the gap has broken down is too low to do any harm to the bushing. In other words, protection is afforded *if the time lag curve of the protective device lies below the time lag curve of the transformer to be protected.* If this is not the case the protective device is useless. For instance, assume that the transformer to be protected has a time lag curve as per curve 3 Figure 26 and a 1½–40 surge wave with a peak value of 60 kv. strikes the assembly.

The curve 1 tells us that the gap breaks down in about 4 micro-seconds and the insulation does not break down. In other words, the insulation of the transformer is protected by the gap.

But if the incoming 1½–40 surge wave has a peak voltage of 80 kv. the insulation of the transformer breaks down in ½ microsecond, that is, before the gap breaks down, which according to curve 1 is about 2½ microseconds. Consequently, the transformer is *not* protected against this surge. If, therefore, *the time lag curves intersect, the transformer is well protected for surge voltage values below the point at which the time lag curves intersect and the transformer is unprotected for other surge voltage values higher than the voltage at which the time lag curves cross.* It will be seen, therefore, that the time lag curve of every part of the transformer as well as of the protective device must be known, in order to predict the ability of the transformer to withstand surges.

Figure 27 gives the time lag curves of an ideally designed and protected transformer. It will be noticed that none of the time lag curves intersect and that the time lag curve of the protector lies at all times materially

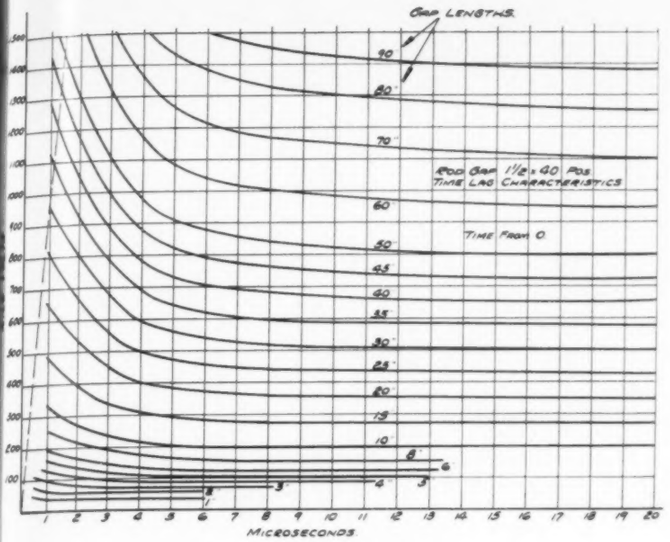


FIGURE 28

below the time lag curve of the bushings. The time lag curves of the bushings lie at all times well below the time lag curve of the major insulation. It may be said the protector represents the first line of defense and the bushing the second line of defense. For completeness sake Figure 28 shows the time lag curves of a number of rod gaps of different lengths.

Figure 29 shows the time lag curve of a

1. Transmission line insulated by 5–10″ disc insulators (curve 1).
2. Certain new station equipment.
3. Rod gap 18¾″ long.

It will be seen that if the time lag characteristics of a station corresponds to these curves, the station equipment is well protected for all surges except from those which are so steep that the rod gap breaks through in less than 1 microsecond.

Now let it be assumed that the station insulation deteriorates and assume a new insulation level as represented by curve. Under these conditions the 18¾″ rod gap protects the equipment only from waves which break the 18¾″ rod gap in more than about 10 microseconds. But full protection can be given to this older equipment if a 6″ rod gap, instead of an 18¾″ rod gap is used as protection as shown by time lag curve.

We have discussed the means available to hold the surge voltages across the different parts of the transformer within safe limits. Interruptions in service due to a breakdown of the transformer should be very rare if it is properly designed and protected.

There is another cause of service interruption often experienced when surge disturbances occur, that is blowing of fuses. Fuses may be blown in two different ways.

1. A follow current may pass through the fuse.
2. The surge current may be of such tremendous magnitude that it blows the fuse in spite of its short duration.

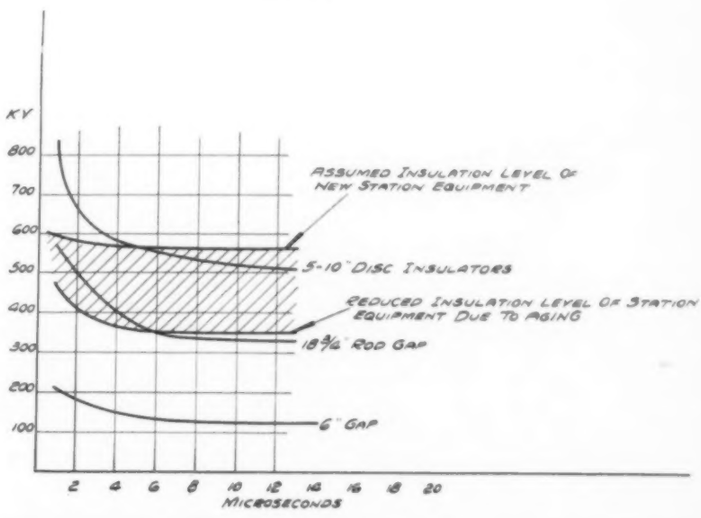
Let us consider first the blowing of fuses due to follow current. It is self-evident that blowing of fuses due to follow current cannot occur if the protective device does not allow any follow current, as in the case of valve type arresters. If the gas quenching gap type protector is used, blowing of fuses is possibly due to the relatively large follow current which may flow for 1/120 second after the surge has been discharged. Naturally blowing of fuses in this case can only occur if the fuse is located ahead of the protector.

If for some very abnormal conditions it should happen that the bushings of a transformer spill over in spite of the fact that they are coordinated with the voltages which can appear across the protector, and in spite of the fact that proper interconnection is used, then in any connection known to the writer a severe follow current takes place provided the resistance, and the time of flashover are such, that the follow current can be established. When and how this occurs has been discussed at the beginning of this paper. In these cases fuses blow no matter whether they are located ahead or behind the protector.

Let us now consider the possibility of blowing fuses due to the surge current alone, that is, under the condition that the surge is discharged to ground without having power current follow. It is evident that no definite statement can be made as to the probability of blowing of fuses by the surge current alone, because the current carried by the surge may vary over a wide range. It is safe to say, however, that the probability of blowing fuses is larger the smaller the fuse capacity, that is, the smaller the rated current of the transformer.

Evidently surge current alone can never blow the fuse if the fuse is located between the protector and the transformer. In this connection it is valuable to have a mental picture of the possible magnitude of the surge current which may be experienced. Figure 30 shows a plot of these currents and is reproduced from an article which appeared in Electrical Engineering, December 1935. For a given fuse rating and make, it is possible to determine by calculation or test the surge current of a 1½–40 wave which will blow the fuse. From such calculations in combination with the curves shown on the previous figure a new set of curves has been prepared which show the possible life of a fuse, see Figure 31. For instance, a 5 ampere fuse on an urban system can be expected to be blown by a surge (not follow current) every 40 years. Or if there are 40 of these fuses in the circuit it may be expected that one of these fuses blows every year due to surge current alone, provided, naturally, that the fuse is mounted ahead of the transformer.

FIGURE 29



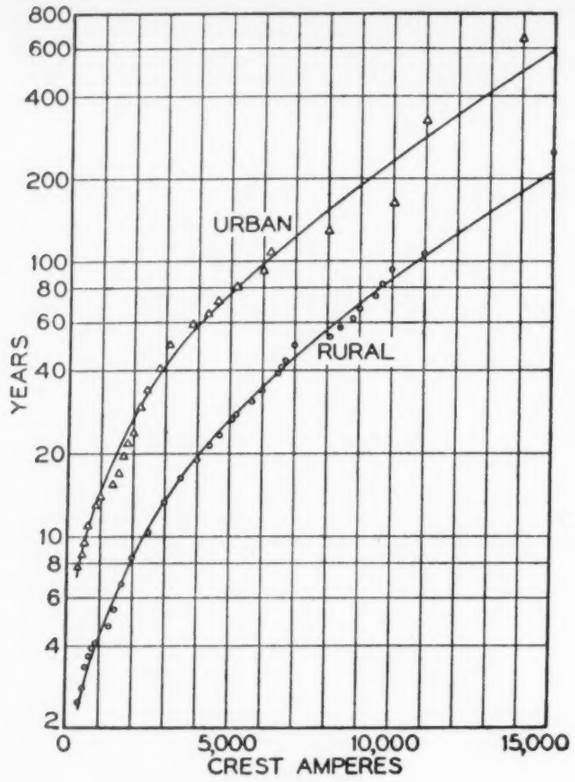


FIGURE 30

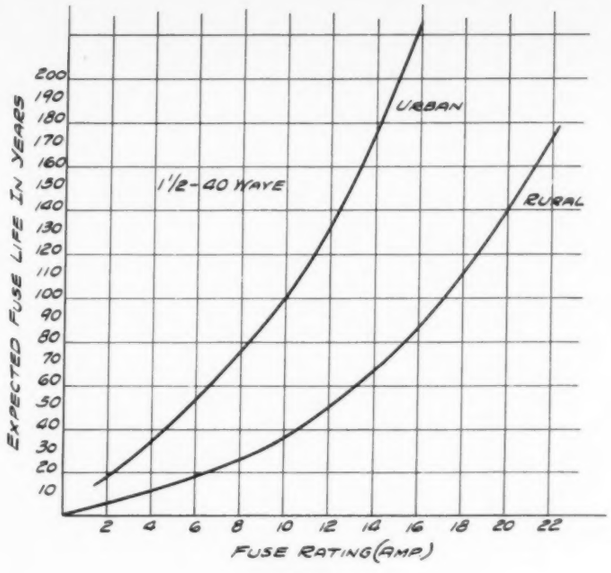


FIGURE 31

DISCUSSION

PRESENTED BY

W. C. SEALY, Allis-Chalmers Manufacturing Co., Milwaukee, Wisconsin

W. E. DOUGLAS, Monongahela West Penn Public Service Co., Pittsburgh, Pa.

H. WEICHSEL, Wagner Electric Company, St. Louis, Mo.

W. C. SEALY: In protecting a transformer against lightning surges by bushing gaps, it is important that the limitations of the bushing gap for protective purposes be realized. Practically, a bushing gap provides very limited protection. That is, it affords protection against only a part of the voltage surges which may reach a transformer.

If a sphere gap could be used, adequate protection could be obtained because its voltage time curve is relatively flat down to small values of time. However, a sphere gap changes its characteristics markedly in the presence of dirt or moisture so that it is not a practical device for this purpose. The gaps used in lightning arresters have much flatter characteristics than the gaps which can be placed on bushings, and, hence, lightning arresters offer the best practical protection against voltage surges. The author indicates that wide margins can be obtained between insulation strength and gap strength. In general, this is not the case. If too small a gap is used, the normal switching surges will cause the gap to flashover with resulting service interruption. From records on operating systems, it is known that switching surges up to 4 times the 60 cycle line to neutral voltage are fairly common. In order that interruption due to normal switching surges may be kept to a reasonable value, the 60 cycle flashover of the bushing gap should be at least equal to 4 times the 60 cycle line to neutral voltage. The following tabulation shows the minimum allowable bushing gap based on switching surges:

TABLE I

Circuit Kv	Length of Test Gap Inches	Assumed Maximum Switching Surge Kv	Calculated Minimum Bushing Gap Inches	Minimum Bushing Gap in % of Test Gap
1.04	.8	2.4	.12	15.0
4.33	2.2	10.0	.5	22.7
8.66	3.3	20.0	1.1	33.3
13.8	4.5	31.9	2.0	44.4
22	7.1	50.8	3.8	53.5
33	10.2	76.2	6.5	63.8
44	13.5	101.5	9.7	71.8
66	20.6	152.5	15.2	73.7
88	27.5	203.0	20.5	74.5
110	34.7	254.0	25.8	74.2
132	42.1	305.0	31.2	74.0
154	49.0	356.0	36.5	74.5
187	60.0	432.0	44.0	73.4
220	70.4	508.0	52.0	74.0
275	88.0	635.0	66.0	75.0
330	105.6	762.0	81.0	76.7

(Some of these gaps are too small to be practical, as, for example, the .12" gap for the lowest circuit voltage.)

For the higher voltage classes the minimum allowable bushing gap is approximately 75 per cent of the test gap. The demonstrated insulation strength of the transformer windings on a 1½–40 wave is that of the test gap. The margin of protection on a 1½–40 wave is 100 to 75, or 1.33. On steeper waves the margin of protection becomes smaller and on very steep waves the insulation is considerably weaker than the gap installed to protect it. Consequently, for steep waves the gap will fail to protect the insulation. Obviously, a gap does afford some protection and is better than no protection.

If transformers or other apparatus are to be operated without failure, they must be protected from direct strokes as the magnitude of the direct stroke may be great enough to damage the insulation. Lightning arresters, gaps or other protective devices will have little effect on the magnitude of a direct stroke occurring at the apparatus. The most effective means of preventing direct stroke is the use of ground wires for at least one-half mile out from the station with lightning arresters at the apparatus. It is important that the arrester be located as close to the apparatus as possible because reflection of the voltage wave may occur at the apparatus. In cases where ground wires are too expensive, the most practical means is to use expulsion gaps on the line insulators for a distance from the station. While the expulsion gaps will not protect against direct strokes, they will limit the value of the surge coming in on the transmission line to a value for which the lightning arrester can protect the transformer.

Protection against lightning surges must start in the design of the transformer. This is true of all transformers, but it is particularly true for higher voltage transformers. Under normal operation every transformer turn has the same voltage across it. When a lightning surge occurs, the voltage tends to concentrate on the line ends at the first moment and then penetrates through the winding increasing the voltage between parts as it penetrates, unless the design is such that the initial distribution through the winding is uniform. In this paper only the major insulation strength has been considered; that is, the insulation strength between windings and to ground. However, the major insulation impulse strength of the transformer may be ample, and the impulse strength between coils and turns of the winding may be inadequate. For lower voltage classes, the method generally employed to obtain the required insulation strength in the winding is to add insulation. On lower voltage classes, this is easily done regardless of the voltage distribution through the winding. On higher voltage transformers, which are designed for correspondingly higher impulse strength, if insulation stresses in the winding are to be kept to a value for which proper insulation can be economically provided, the surge voltage must be distributed uniformly through the winding. To secure this uniform voltage distribution, there are two methods; (1) to design the transformer with such proportions that it inherently has good voltage distribution, (2) to design the transformer with inherently poor voltage distribution and put in other means to improve the voltage distribution. Both methods have been used in building transformers to withstand specified impulse tests. The first method is the simpler because it does not add to the complication of the transformer or introduce additional stresses in the transformer. The second method is usually employed for core type transformers, for the first method results in uneconomical proportions and unsatisfactory oil circulation for cooling this type.

The inherently poor voltage distribution of a core type transformer under surge conditions is improved by the addition of a comparatively large number of shields connected to the line terminals. These shields reduce the voltage stresses in the windings under surge conditions, but they introduce new voltage concentrations of large magnitude between themselves and the coils. The principal disadvantage of this method is the difficulty of providing sufficient insulation for the high voltage concentrations between the shields and the coils without too greatly obstructing oil circulation for cooling.

In the case of shell type transformers, the first method can be used by designing the transformer with proper mechanical proportions. Such a design is practicable, as the resulting proportions (which do not differ greatly from normal proportions for this type of transformer) allow free oil circulation with the usual type of solid insulation between the coils.

This outlines the general methods of designing transformers so they can be protected from impulses of given characteristics.

A great variety of papers have been published on the subject of surges. The most representative have been collected and published recently as the "A.I.E.E. Lightning Reference Book."

W. E. Douglas: Mr. Weischsel has set forth in his paper, very clearly, what may be expected of various types of protective equipment under transient conditions of abnormal voltage and as this discussion is being written, Mother Nature is conducting a practical demonstration of how certain steep wave front surges originate.

The effects and principles outlined in this paper apply generally, but they are of particular importance in the protection of distribution transformers supplying a residential load. Public Utilities in particular have the problem of protecting the distribution transformers very much in mind due to the cost of replacing the blown fuses and the annoyance of interruptions in service. Mill villages are usually fed from distribution circuits to which attention should be paid for the maximum lightning protection.

Within steel mills proper there are, in some plants, circuits exposed to lightning disturbances. These are principally circuits between buildings with protective equipment at their terminals, and, when mounted on steel poles, these lines have relatively low surge insulation to ground on account of the fact that there is only the porcelain insulator limiting the line to ground flashover, instead of the porcelain on a relatively long crossarm and pole of wood construction as used in distribution practice. The high surge insulation of these distribution lines will permit the transmission of surges of high magnitude for greater distances than will the lines common to steel mill practice, and as the insulation to ground is increased, the terminal lightning arresters have an increased influence in pre-

venting outages, since the surge can arrive at the arrester before the line flashes over.

In steel mills it is not uncommon to connect high voltage motors to over-head lines having exposure to lightning. Transformers can be so designed that the rate of rise of the surge voltage has relatively little effect. Motors, on account of their mechanical structure, have relatively low levels of insulation to such surges and for protection it is necessary to limit the rate of rise of voltage as well as its magnitude in order to prevent failures across the end turns of the motor winding. This surge protection usually takes the form of a capacitor to slope off the wave front and in addition a lightning arrester to limit the voltage that can appear on the capacitor.

In speaking of the probability of outages, it was stated that with the arrester on the transformer side of the fuses an outage resulting from lightning would not be expected more than once in 40 years. This may be slightly misleading as to the vulnerability of these transformers. This rate of blowing a five ampere fuse might better be expressed in the terms of one outage per 40 transformers in service per year. Where such a low current fuse must be applied it might be desirable to connect it between the arrester and the transformer, which is the practice in the Utility with which I am connected. Where fuses of approximately 20 amperes rating are used, the probability of outage resulting from the blowing of a fuse on surge becomes relatively small.

H. WEICHSEL: It is impossible to cover in the limited space of a paper all of the large number of different effects which surges can and do produce. The paper, therefore, is limited to the basic principles which enter in the problem of protecting existing transformers. In other words, it describes means for limiting the surge voltage values between transformer windings and ground. No further reference to the actual design of the transformer was made except as was stated: "Interruption of service due to break down of the transformer should be very rare if it is properly designed and protected". Mr. Sealy describes in his discussion some of the means used in accomplishing said "proper designs". The two methods cited by him have been known to the designing engineers for many years. The second of the methods he refers to consists in placing means, for instance "shields", in or on transformer windings to improve the surge voltage distribution along the winding. It is strange that this method became more generally known only during the last few years, in spite of the fact that to my knowledge the first U. S. A. patent on partially shielding was issued in the year 1912, and fully shielded transformers were used in Europe as far back as 1921.

Apparently Mr. Sealy misunderstood me regarding the use of bushing gaps. It was not my intention to advocate bushing gaps as the sole protection of transformers. On the contrary, protecting devices such as arresters should be used in combination with bushing gaps. The paper states, "The protector represents the first line of defense, and the bushing the second line of defense". In other words, the arresters or their equivalent present the real protection but, if for some abnormal conditions this first line of defense should fail, then the bushing gap acts as the second line of defense. Consequently it is not so important to have these gaps act as definitely as the arresters. It is generally accepted that under favorable conditions sphere gaps have better performance than bushing gaps or rod gaps, because they possess first, no time lag for all waves except those with extremely steep fronts, provided the spacing is not materially larger than one half the sphere diameter. Second, their characteristic is independent of the air humidity.

Experience, however, has shown that in spite of these superior characteristics the sphere gaps are not practical for field work as their characteristics depend on the surface condition of the sphere.

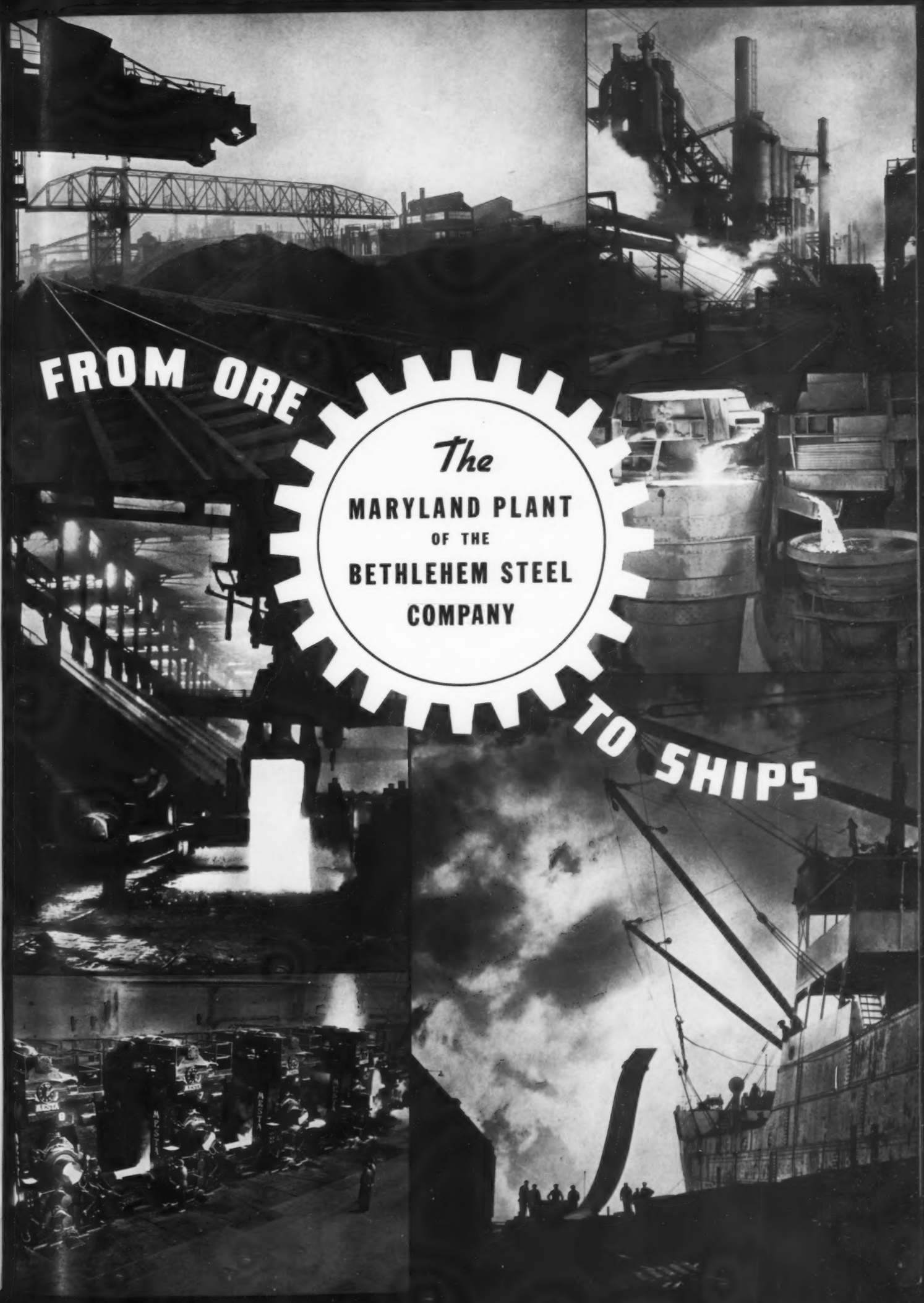
In some installations when rod gaps are used as the sole protection, it is advisable to set the gap as low as possible. Mr. Sealy points out that too low a setting of these gaps may lead to frequent service interruption. It should be stated here that these service interruptions occur only if the spill over of the gap initiates a follow current. Fortunately, there are certain gaps on the market which prevent objectionable follow currents. The gap settings shown on Figure 29 in the paper are based on data published by the Wolff Manufacturing Company, which manufactures gaps designed to prevent or limit follow currents, thus making it possible to use gap spacings considerably less than those proposed by the A.I.E.E. Field experience has shown that equipment protected by "short gaps" possessing the above characteristics give superior service.

Protecting transformers against direct strokes is a much disputed question in view of the fact that direct strokes are extremely rare as will be seen from Figure 30 in my paper. In cases where it is desired to protect against this more or less rare phenomena, it is possible to make use of expulsion gaps or similar protecting devices as stated by Mr. Sealy.

It is very gratifying to see that the discussion points out again the importance of placing the arrester as close to the apparatus as possible. This arrangement was already mentioned in the paper, but its importance cannot be emphasized too much.

I am in full agreement with all the statements made by Mr. Douglas and it is very timely that he refers to surge protection of motors by use of suitable capacitors.

A great deal of field, laboratory, and theoretical study has been given to this important subject of surges. As stated in the discussion, the most important publications prior to 1935 in this field can be found in the A.I.E.E. Lightning Reference Book. It should not be overlooked, however, that new researches and developments take place continuously and that for this reason it is advisable to keep in close touch with current literature.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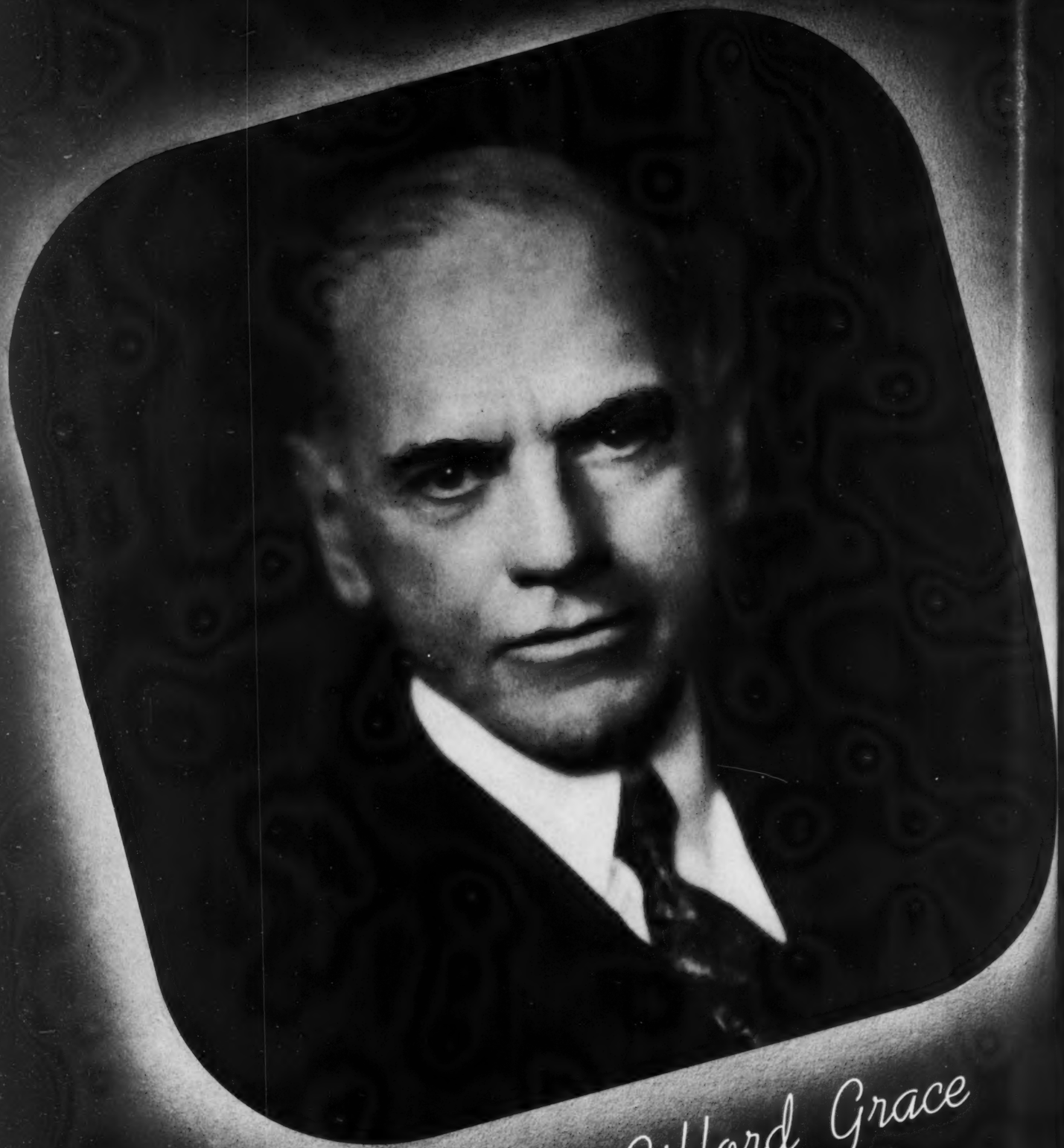

Eugene Gifford Grace

PRESIDENT

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Eugene Gifford Grace

Paralleling the history of the development of Bethlehem Steel Corporation runs the story of Eugene Gifford Grace, and so interlocked are they that either story, without consideration of the other, is incomplete . . . for the growth of Bethlehem is almost synonomous with the rise of Grace.

Born in a small community, Goshen, N. J., on August 27th, 1876, his higher education led him to Lehigh University, where he was graduated in electrical engineering in 1899. In the same year, he started work as an electric crane operator with Bethlehem Steel Company, and, progressing rapidly to various other duties in the steel plant, became superintendent of yard and transportation departments in 1902.

With the purchase of Bethlehem Steel by Charles M. Schwab in 1905 came the Schwab policy of developing his organization from within, rather than going outside for key men, and Bethlehem's progress gives ample justification of this policy. After a period in Cuba with the Juragua Iron Company, a Bethlehem subsidiary, Eugene Grace was made, successively, general superintendent, general manager, vice-president, and president of Bethlehem Steel Company, and finally, in 1916, president of the Bethlehem Steel Corporation.

This step, putting a man of forty years of age in complete charge of the manifold activities of a huge industrial corporation, was somewhat revolutionary at the time, but the wisdom of Schwab's move has been borne out, and the industry has since witnessed many similar steps.

The advent of the World War brought a virtual wave of business to Bethlehem, and strained the capacity of the company to the utmost, but so able was the administration of Mr. Grace that Bethlehem supplied a very considerable portion of the output of armament and war materials, and on the return of peace, promptly returned to a peace-time footing.

The history of Bethlehem under the management of Mr. Grace shows steady expansion and progress, both in size and in technical improvement. Producing capacity has been increased some twelve-fold, largely by the merging of existing plants, a procedure found most effective due to the acquisition of good-will and personnel as well as a going plant. A constant plan of development and modernization has also been carried along in all of the corporation's plants, which can now boast of some of the most modern and efficient equipment in the industry.

Throughout his rapid progress . . . and no doubt at the root of it . . . Mr. Grace carried the determination to excel in his particular position. Even as he had led his class in the university, so he strove to lead in his industrial life . . . and so thoroughly has this attitude permeated his entire life that it has been carried over into his recreation, as testified to by his numerous golf trophies. Recreation and exercise, he holds, are essential for mental alertness and working efficiency.

This intense desire to lead, and the speedy advancement resulting from it, however, has not resulted in a dictatorial attitude, but rather the reverse. Extremely open-minded and interested in other's view-points, the Grace policy calls for management by a group of executives in close contact, each responsible for his own work in his own way, but functioning as a coordinated part of the whole unit. This idea is carried down throughout the entire organization, and has done much to develop personnel and to increase efficiency, both in the management and operating units.

Warm-hearted and friendly, with a lively interest in his employees' welfare, Mr. Grace pioneered in a wide program of employee security and relations, holding to a strict code of ideals and ethics, and firmly guiding the corporation in such a way as to be fair to workmen, investors, and the public. To him, industrial enterprise is a serious responsibility which he feels keenly and labors diligently to fulfill. In spite of the great size of the far-flung Bethlehem empire, the serious yet genial spirit of Eugene Grace pervades the entire organization . . . guiding, leading, inspiring . . . with a marked influence extending beyond the borders of his own corporation and throughout the entire steel industry.

FROM ORE

The MARYLAND PLANT OF THE BETHLEHEM STEEL COMPANY

TO SHIP

▲ IT is a far cry from the original blast furnace, built by the Pennsylvania Steel Company about fifty years ago on the banks of the Patapsco River, to the huge, modern, integrated plant which today is known as the Maryland Plant of the Bethlehem Steel Company.

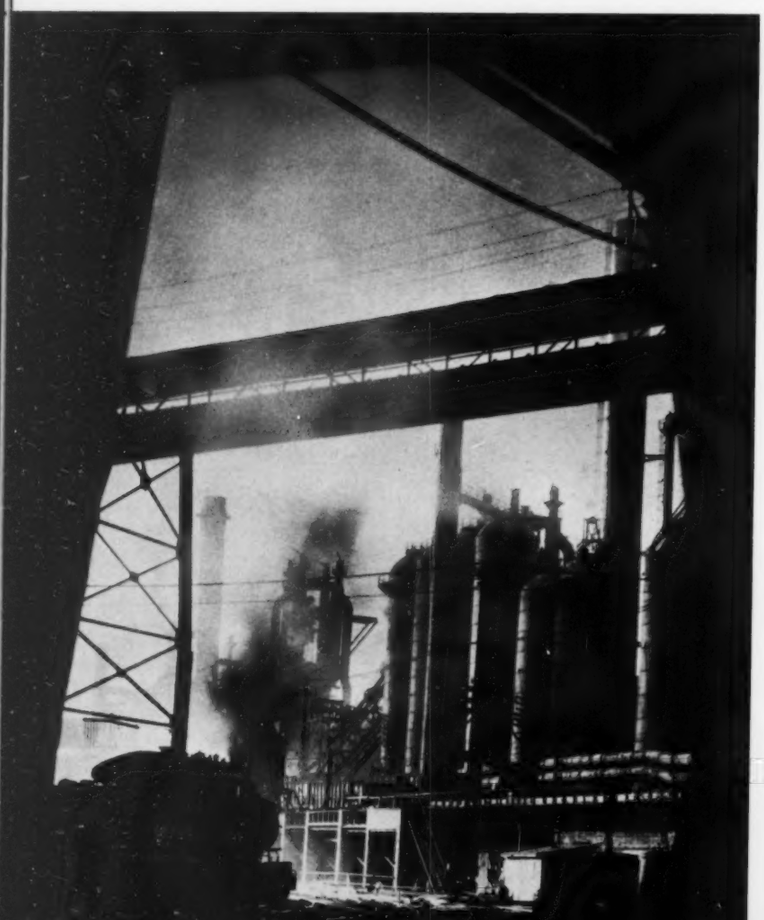
Located on a site 12 miles southeast of Baltimore known as Sparrows Point, it is the only large steel plant in the United States on tidewater, which enables it to receive raw materials and to ship products in ocean-going vessels.

The site totals 2304 acres of land, which is made up of 974 acres for the steel plant proper, 102 acres for shipyard activities, and the balance of 1228 acres for reserve plant land and the town of Sparrows Point.

The development of this plant has, for the greater part, occurred since 1916, in which year this entire plant was taken over by the Bethlehem Steel Company, and through reconstruction and enlargement, has since become one of the largest in the country, with a steel ingot capacity of 2,965,000 gross tons per year. Principal products include pig iron, rails, plates, flanged heads, skelp, billets, sheet bar, tin and black plate, plain and galvanized sheets, hot and cold rolled strip, wire rods, wire and wire products, butt- and lap-welded pipe, castings and ships.

Extending along the river is the ore dock, 1200 ft. long, with a storage capacity of about half a million tons. The ore dock is provided with two 46-ft. span mechanical ore unloaders, one 250-ft. span handling bridge, and two 366-ft. span unloader bridges. Limestone is received principally from Pennsylvania, by rail.

At another location, also along the river, is the coal dock, equipped with two 361-ft. span unloader bridges. Coal arrives at the plant principally by boat or barge from nearby ports to which it has been carried by rail from the Company's mines in Pennsylvania and West Virginia. Coal storage averages about 150,000 gross tons. Normal plant operation requires about 2,200,000 gross tons of bituminous coal annually.



There are six blast furnaces, located in a line paralleling the row of coke batteries, with a total annual capacity of about 1,880,000 gross tons of pig iron.

COKE PLANT

The by-product coke plant, which is located adjacent to the coal dock, consists of 361 ovens, arranged in six batteries, and capable of carbonizing 6000 tons of bituminous coal per day. One battery is of the Becker type and the other five of the Koppers type ovens. Oven dimensions average about 19¾″ wide x 39′–0″ long x 9′–6″ high. Oven charges are 12–13 gross tons per oven of a mixture of low, medium and high volatile coals. Five batteries are heated with coke oven gas, and one with blast furnace gas. Coking time is said to be 17½ hours minimum. Metallurgical coke production from operation of the six batteries totals about 4260 tons per day, which is consumed in the plant. Coke yield is about 72%.

Recovery of by-products follows the common practice. By-product yields are given as approximately 11,500 cu. ft. of gas, 9¼ gal. of tar, 3.5 gal. of light oils

and 24½ lb. of ammonium sulphate per gross ton of coal. Surplus gas, which runs about 60% of the gas make, is divided between sale to the city of Baltimore and various reheating operations in the plant. The other by-products are sold.

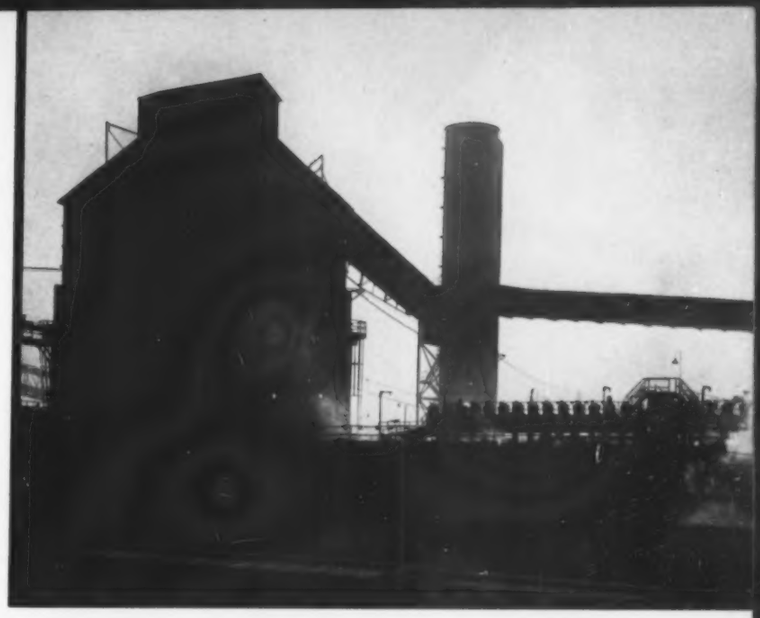
BLAST FURNACES

There are six blast furnaces, located in a line paralleling the row of coke batteries, with a total annual capacity of about 1,880,000 gross tons of pig iron. An average coke rate of about 1700 lb. per gross ton of iron is obtained. Blast temperatures are carried at 1350–1600 degrees F., according to furnace conditions, and the stoves are said to consume about 24% of the total blast furnace gas make. Surplus gas is used to underfire one battery of coke ovens, in soaking pits, in gas electric and blowing engines, and under boilers.

Blast furnace gas is brought to a high degree of cleanliness by a very efficient cleaning system. Each furnace is equipped with a tangential dust catcher and a wet tower washer. There are also five disintegrators for final cleaning. Dust content of the gas in this equipment is approximately 1.–6. grains per cu. ft. leaving the dust catcher, .25 grains per cu. ft. leaving the wet washer, and .015 grains per cu. ft. leaving the disintegrators.

Blast for the furnaces is supplied by fourteen gas-driven blowing engines and three steam turbo-blowers, with a total combined capacity of 550,000 cu. ft. of air per minute. Blast pressures range 15–30 lb. per sq. in.

Hot iron from the blast furnaces may be sent to the open hearths, to the Bessemers, or to the pig machine. There is one two-strand pig machine. Hot metal is handled in six 125-ton mixer type ladles and twenty-eight 40-ton open top ladles.



The by-product coke plant located adjacent to the coal dock consists of 361 ovens, arranged in six batteries and capable of carbonizing 6000 tons of bituminous coal per day.

In the January 7, 1926 issue of "IRON AGE", Charles M. Schwab, Chairman, Bethlehem Steel Corporation, stated that: "My hope is that eventually we shall have at Sparrows Point, the greatest steel plant in the world." While Mr. Schwab's expression was a hope rather than a prediction, there is little doubt his wish has been granted. The IRON & STEEL ENGINEER considers itself honored to have the privilege of recording the development and expansion of this great steel plant.

MIXED GAS SYSTEM

There is a central gas mixing station where coke oven gas is mixed with some blast furnace gas, so as to obtain a 500 Btu. per cu. ft. mixture. The mixing is controlled by a butterfly valve and an iris valve on each of the two gas supply lines, with automatic pressure regulation. A calorimeter controls and furnishes a constant check on the heat value of the mixed gas.

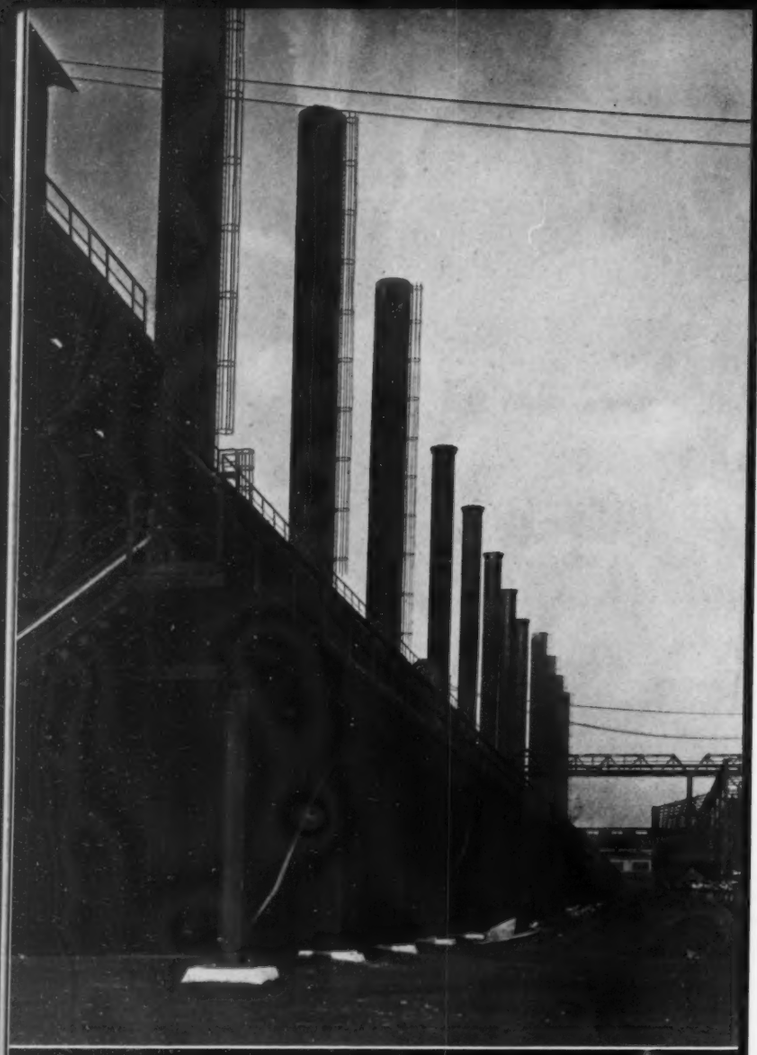
The 500 Btu. gas is then piped around the mills at 10–12 lb. pressure, serving the hot strip, sheet and tin mills, rod and wire mills, rail mill, miscellaneous heating, open hearth auxiliaries and shipyard. A line also runs to the soaking pits, together with a blast furnace gas line, where two more mixing stations produce lean gas of 100 and 130 Btu. per cu. ft. respectively, for use in the pit furnaces.

Under normal conditions, about 40% of the surplus coke gas is used in the plant, while the other 60% is sold to the city of Baltimore.

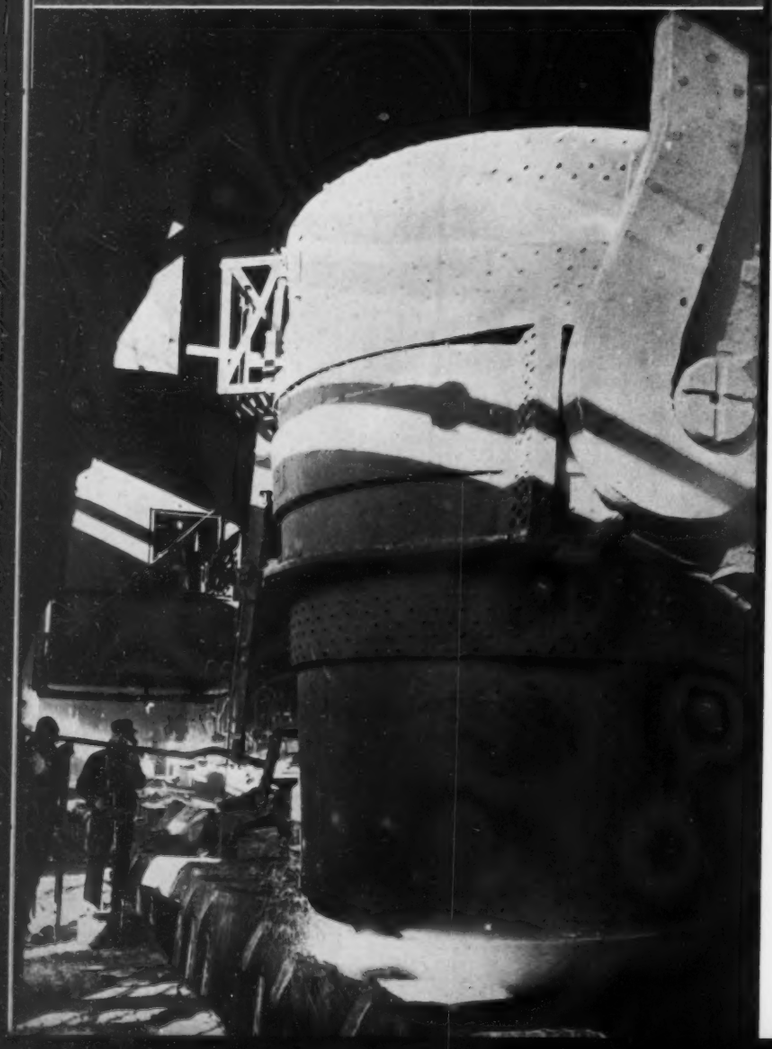
OPEN HEARTH AND BESSEMER

At right angles to the row of blast furnaces lay three open hearth shops, parallel to each other, representing a total capacity of about 220,000 gross tons of open hearth steel, and 25,000 gross tons of Bessemer steel per month.

No. 1 Open Hearth is composed of twelve furnaces, rated at 150 tons, housed in a building 1237 ft. long x 141 ft. wide. Hearth dimensions of nine of these furnaces are 43′–4″ x 16′–10″, with an area of 729 sq. ft., and for the other three, 49′–5″ x 16′–10″, with an area of 830 sq. ft. A 1000-ton mixer is installed in this building. This shop is served by four pit ladle cranes, three of 150-ton capacity and one of 175-tons. There



Open hearth shop which there are three laying parallel to each other and having a total monthly capacity of 220,000 gross tons of open hearth steel.



Pouring steel from the open hearth into a train of ingot molds for further transportation to the soaking pits.

are three 75-ton floor ladle cranes to handle hot metal from mixer to the furnaces in 65-ton ladles. Another 75-ton ladle crane serves the mixer in this plant.

No. 2 Open Hearth is a building 1027 ft. long x 163 ft. wide, containing five 150-ton furnaces, three 20-ton Bessemer converters, and three hot metal mixers of 1300 tons, 700 tons and 450 tons capacity respectively. These furnaces have hearths 44′–6″ x 19′–0″, with an area of 845 sq. ft. There are two 175-ton pit ladle cranes in this building, besides three 100-ton floor ladle cranes, and one 100-ton ladle crane for the mixer. A 60-ton ladle crane is provided for the Bessemers, which tap into 25-ton ladles. Open hearth furnaces in both No. 1 and No. 2 shops tap into 150-ton ladles.

No. 3 Open Hearth contains six 150-ton furnaces, housed in a building 700 ft. long x 165 ft. wide. Immediately adjacent is a building 225 ft. long x 90 ft. wide, containing a 1300-ton and a 600-ton mixer. The furnaces in this shop have hearths 52′–6″ x 16′–10″, with areas of 884 sq. ft. The 175-ton tapping ladles in this shop are handled by two 200-ton ladle cranes. Two 100-ton floor ladle cranes are also provided, and another 100-ton ladle crane serves the mixer for this shop.

All open hearth furnace roofs are of bonded sprung arch construction, 13½″ thick. All furnaces have the bulkheads, slag-pockets, necks and regenerators covered with a sprayed sealing coat. All bulkheads above the charging floor have a 2½″ coating of insulation. Two sets of regenerators in No. 2 shop and five sets of regenerators in No. 1 shop have 3½″ thickness of natural coarse insulation encased with ¼″ steel plate. All furnaces in No. 3 shop are completely insulated and the regenerators are steel encased.

All open hearths are fired with fuel oil. Average fuel consumptions are given as 4.12 million Btu. for No. 1 open hearth, 3.72 million Btu. for No. 2 open hearth and 3.14 million Btu. for No. 3 open hearth, per gross ton of steel. Time of heats averages about 9½ hours. Forced draft fans supply air to all furnaces.

Instruments and controls have been extensively applied in the open hearths. Each furnace is equipped with an oil flowmeter, flue gas pyrometer, roof temperature potentiometer, automatic time reversal, draft gauge, oil regulating valves, furnace pressure control and forced draft control.

There are seven 600 H.P. waste-heat boilers installed in conjunction with No. 1 Open Hearth. They are of the horizontal fire-tube type, 9′–6″ diameter x 21′-11″ long, each containing 470 tubes 2½″ O.D., built for 160 lb. pressure, 150 degrees superheat. They are equipped with 8½ ft. double suction fans with a capac-

Instrumentation has been extensively applied in the open hearths; assuring close metallurgical control of the metal while in the furnace.

A wide variety of ingot molds are available so a choice may be made to best fit the product desired.

ity of 120,000 lb. of waste gases at 500–700 degrees temperature, driven by a 100 H.P., 300/500 R.P.M. motor. No. 2 Open Hearth is provided with five waste-heat boilers, one of which is a duplicate of the above, while the other four are cross-drum type, of 654 HP. rating. Working conditions are 160 lb. pressure, 100 degrees superheat. Each of these boilers produces an average of about 480 boiler HP. There are no boilers in No. 3 Open Hearth.

SOAKING PITS

Steel from open hearths and Bessemers are poured into a wide variety of ingot moulds, so that the ingot may be chosen to best fit the product desired. The active list of moulds covers a wide range of shapes, in weights running from 4760 lb. up to 48,204 lb. Moulds within limits of the stripping crane capacities are stripped from the ingots at three stripper buildings and the ingots brought to the soaking pits on narrow gauge ingot mould cars.

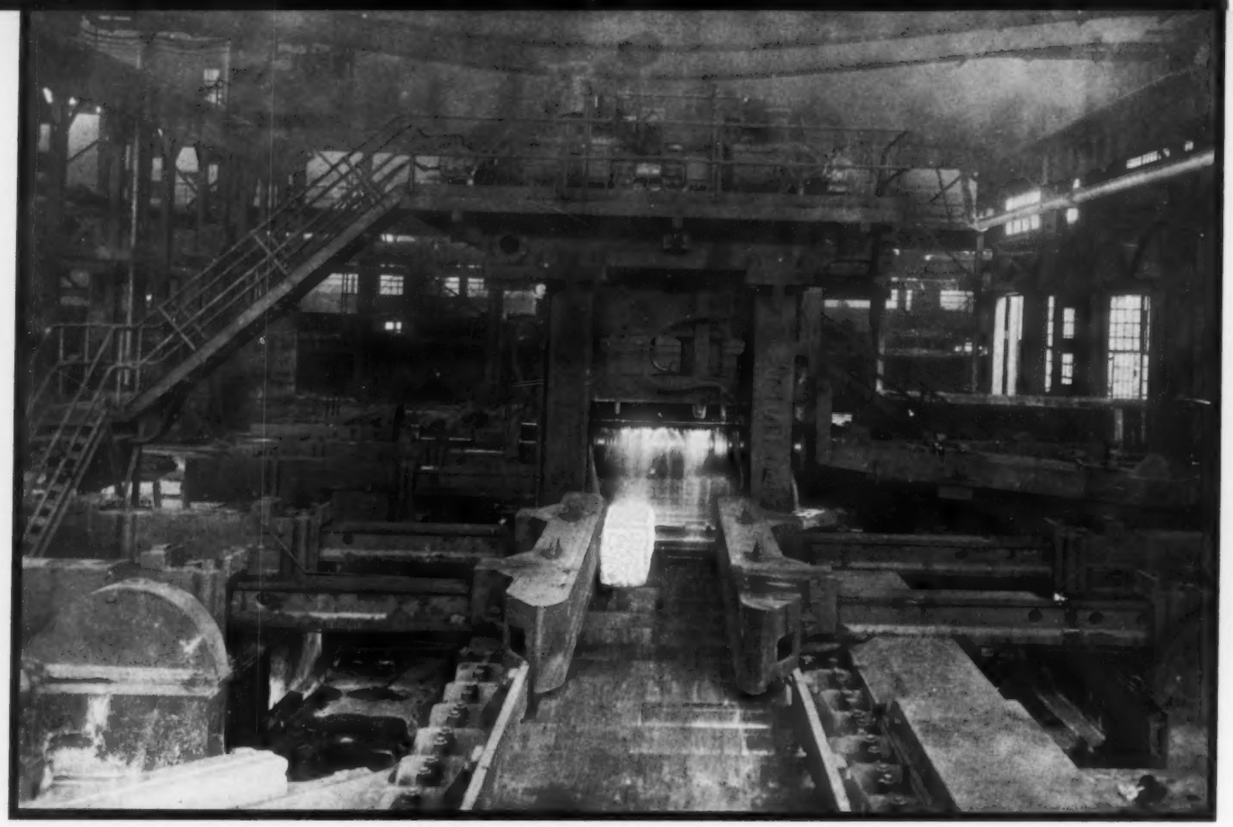
There are 22 blocks of soaking pits, with 4 holes per block. The holes are of the following dimensions:

	Width	Length	Depth
6 Blocks	6′–0″	8′–9″	8′–7¼″
1 Block	6′–7″	8′–9″	8′–7¼″
7 Blocks	7′–0″	9′–0″	8′–7¼″
8 Blocks	7′–0″	11′–0″	9′–0″

Fourteen blocks are fired with a mixed gas of 130 Btu. per cu. ft., while the other eight blocks are fired with blast furnace gas of approximately 100 Btu. per cu. ft. The pits are well equipped with controls, having gas pressure regulators and gauges, gas flow indicators, and automatic time reversal mechanism.

From two to six ingots are usually charged in each hole, depending on their size. Ingots are put into the pits by travelling pit crane, and when withdrawn by

Soaking pits of which there are twenty-two blocks, with four holes per block, are well equipped with controls.



One of two blooming mills the above illustration shows the 46″ mill. This blooming mill rolls sizes ranging from 6″ x 6″ to 22″ x 46″.

the same means are placed on standard gauge ingot buggies, propelled by electric locomotives. When car is opposite either the blooming or slabbing mill approach tables, an electrically driven crank motion tilts the buggy and deposits the ingot on the roller table. Ingot sizes usually fall between 22″ x 24″ and 32″ x 50″.

BLOOM, BILLET AND SLAB MILLS

There are two blooming mills, each with a capacity of 120–150 gross tons per hour, finished weight. The older mill is a 40″ reversing mill, with rolls 38¾″ in diameter x 92″ body length, running in babbitted bearings with brass grid inserts. This mill is driven by a 7000 HP., 600 volt DC., 500-100 RPM. motor, using two 3500 HP. armatures on one shaft. This motor draws power from a dual flywheel motor generator set consisting of two 3000 KW., 600 volt DC. generators driven at 370 RPM. by a 5000 HP., 6600 volt, 25 cycle slip ring motor with forced ventilation. A 1200 ton steam hydraulic shear, with intensifier, serves this mill. Product of the mill ranges 6″ x 6″ to 5½″ x 22″.

The second blooming mill is a 46″ reversing stand, with rolls 40″ x 92″, and is driven by a 7000 HP., 650 volt DC., 50-100 RPM. motor, also using two 3500 HP. armatures on one shaft. The flywheel M.G. set for this drive consists of two 3000 KW., 650 volt DC. generators, driven at 370 RPM. by a 5000 HP., 6600 volt, 25 cycle slip ring motor. Mill bearings are of the same type as in the 40″ mill. In both stands, the mill bearings are lubricated with hot neck grease, hand packed. The 46″ mill rolls sizes running from 6″ x 6″ to 22″ x 46″. This mill is provided with a 3000 ton steam hydraulic shear.

Mill tables and auxiliaries are driven by 230 volt DC. mill type motors. Table rollers run in bronze bearings, lubricated by grease systems.

A continuous 24″–18″ billet mill lays behind the blooming mills, from which it receives blooms usually 8″ x 8″ in size. It has a capacity of 110–120 gross tons per hour, and produces standard billets 1¾″ to 3″ square, as well as a variety of skelp blanks. The mill consists of six 24″ x 60″ roughing stands, followed by six 18″ x 27″ finishers. A vertical edger is placed between No. 4 and No. 5 stands in the roughing train, and another just ahead of the finishing train. The mill has delivery speed of 640 ft. per minute. It is driven by a 4000 HP., 6600 volt, 83 RPM. motor on the roughers, and a 3250 HP., 6600 volt, 94 RPM. motor on the finishing train. Each edger is driven by a 250 HP., 300-475 RPM., 250 volt DC. motor.

In this same building is located a continuous 27″–24″–21″ sheet bar mill, consisting of two 27″ roughers, two 24″ roughers and seven 21″ finishing stands. An edger is placed between the third and fourth rougher, another preceding the third finisher, and a third preceding the fifth finisher. This mill takes 7⅞″ x 8⅛″ blooms direct from the blooming mills for the production of sheet bar, or slabs up to 6″ thick for the production of skelp. Product from the mill ranges 8″–22¼″ in width x .187″–1.5″ in thickness. A production rate of 120–130 gross tons per hour may be maintained, the steel being given 9–11 passes, with reductions in each pass running from 15% to 50%. A maximum delivery speed of 790 ft. per minute may be reached from the last finishing stand. The 27″ stands are driven by a 4000 HP., 6600 volt, 83.3 R.P.M. synchronous motor, the 24″ stands by a 6500 HP., 6600 volt, 187.5 RPM. synchronous motor, and the 21″ stands by a 6700/5000/3350 HP., 6600 volt, 500/375/250 RPM. Scherbius controlled motor.

Large slabs, 18″–60″ in width and 4″–22″ thick, are produced on a 40″ universal reversing slabbing mill,

Exterior view of the rail mill building. This product has always constituted one of this plant's principal products. Rails of 50-131 lb. per yard are rolled.

with a capacity of 120–130 gross tons per hour. Horizontal rolls are 40″ diameter x 80″ long, and run in babbitt bearings with brass inserts. They are driven by a 7000 HP., 50/80 RPM., 650 volt DC. motor. The vertical rolls, 24″ in diameter, are driven by a 2500 HP., 100/250 RPM., 650 volt D.C. motor. Both of these motors draw power from a flywheel motor generator set made up of three 3000 KW., 650 volt DC. generators driven at 375 RPM., by a 6000 HP., 6600 volt, 25 cycle induction motor. Ingots for this mill ranging from 22″ x 24″ to 37″ x 64″, are heated in the soaking pits previously mentioned, which are arranged in one line so that any pit will serve either blooming mill or slabbing mill. Pressure grease lubricating systems, both automatic and hand-operated serve the entire mill, including horizontal and vertical roll bearings.

RAIL MILL

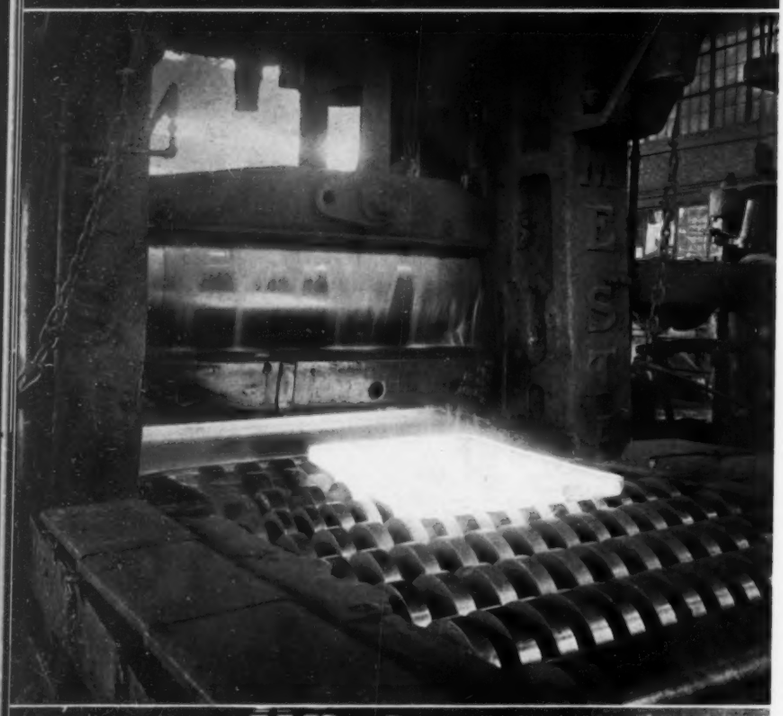
Ever since the early years of this plant, rails have constituted one of its principal products, capacity for which is provided by a 26″ three-high rail mill. This mill rolls rails of 50-131 lb. per yard. The steel is handled through this mill by electrically operated elevating, tilting and manipulating tables. A hot saw follows the mill, delivering on to a group of 60 ft. hot beds.

PLATE MILLS

Three plate mills afford facilities for producing sheared and universal plates in a wide range of widths and thicknesses. The 36″ x 110″ plate mill produces sheared plate of 100″ x 5″ maximum, 72″ x ⅛″ minimum dimensions from slabs ranging 16″ x 58″, 20,000 lb., down to 2″ x 20″, 500 lb. The mill has a capacity of 20 gross tons per hour, and consists of a single 3-high stand, driven at 53 RPM. by a 4000 HP., 6600 volt motor. Top and bottom rolls are 38″ diameter x 114″ long, and the middle roll is 24″ x 114″. The mill is served by six reversing regenerative furnaces, with 8′-3 x 34′ hearths, fired through the roof with mechanical oil atomizers.

The 60″ universal plate mill consists of one 2-high reversing stand, with 36″ x 84″ horizontal rolls, and 21″ vertical rolls. This mill is driven by a 4400 HP., 700 volt DC., 50-100 RPM. motor. The flywheel M.G. set for this drive consists of two 2200 KW., 700 volt DC. generators driven at 370 RPM. by a 5000 HP., 6600 volt, 25 cycle slip ring motor. The horizontal rolls are driven direct, while the vertical rolls are geared up in a ratio of approximately 1:1.7. Slabs

The 60″ universal plate mill shown below consists of one 2-high reversing stand, with 36″ x 84″ horizontal rolls, and 21″ vertical rolls.



of 20″ x 58″, 35,000 lb., down to 5″ x 10″, 1200 lb., are reduced to plates ranging 58″–10″ in width. Mill capacity is about 25 gross tons per hour. Heating facilities are provided by six reversing regenerative furnaces, duplicating those on the 110″ plate mill. A 160″ plate mill rounds out plate producing units, and produces sheared plate up to 145″–150″ wide, in thicknesses ranging from 3/8″ up to 12″. Ingots, from a maximum of 28″ x 90″, 50,000 lb., to slabs of a minimum of 6″ x 40″, 2500 lb., are heated in three reversing, regenerative, roof oil-fired furnaces, 10′–4″ x 42′–0″. The furnaces are completely equipped with automatic controls. The mill consists of a single 3-high stand, with top and bottom rolls 44½″ x 160″, and middle rolls 27½″ x 160″, driven at 37.5 RPM., through gears by a 4500 HP., 6600 volt, 370 RPM. motor. Mill capacity averages 22 gross tons per hour.

A flanging shop provides facilities for converting plate into the various types of flanged products required for boilers, tanks and similar applications.

SKELP MILL

There is also a 12″ continuous skelp mill, which provides skelp for the pipe mills and semi-finished material for the outside trade. Product from this mill ranges from 1⅝″ to 8 3/16″ wide x .08 to .300″ thick, being rolled from billets 5½″–7⅞″ wide x 2″ thick, or 1 15/16″–3″ squares. The mill consists of four roughing stands, two intermediate stands and two finishing stands. An edger precedes each of these three groups. Roughers are driven through gears by an 1800 HP., 275/550 RPM., 600 volt DC motor. The intermediate stands are driven by a duplicate motor. Each of the two finishing stands is driven direct by an 1100 HP., 600 volt DC. motor of 214/320 and 246/382 RPM. respectively. Production of this mill is limited to a maximum of about 35 gross tons per hour by the capacity of the heating furnace, which is a 25′ x 30′ continuous billet heating furnace, fired with producer gas. The mill, with a maximum delivery speed of 1225 ft. per minute, is faster than the furnace widths above 4¼″.

PIPE MILLS

The rod and wire mills are located on a point of land reached from the balance of the plant over a narrow

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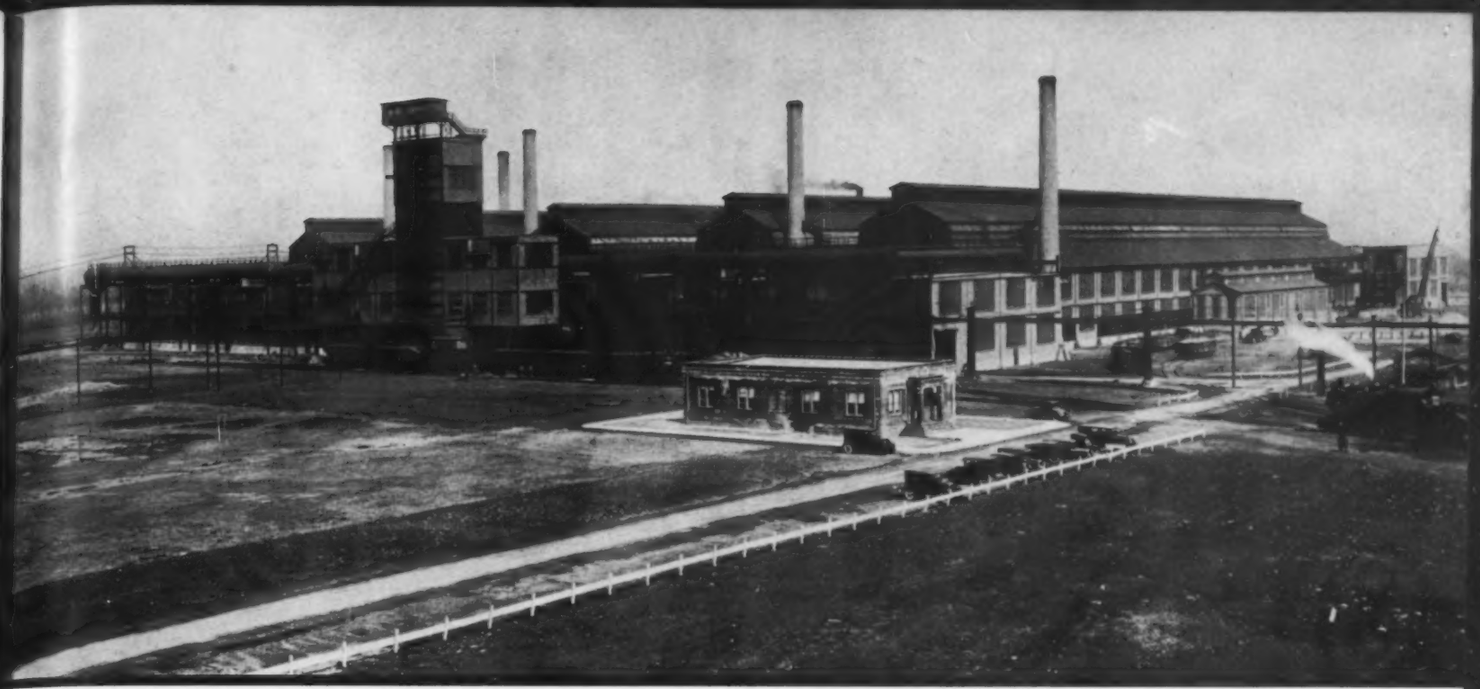
The upper left illustration showing the 160″ plate mill rounds out the plate producing units of this Maryland Plant. Its capacity averages 22 gross tons per hour. The center illustration is that of the 110″ plate mill which has a capacity of 20 gross tons per hour. The bottom picture shows the flanging department which has facilities for converting plate into various types of flanged products.



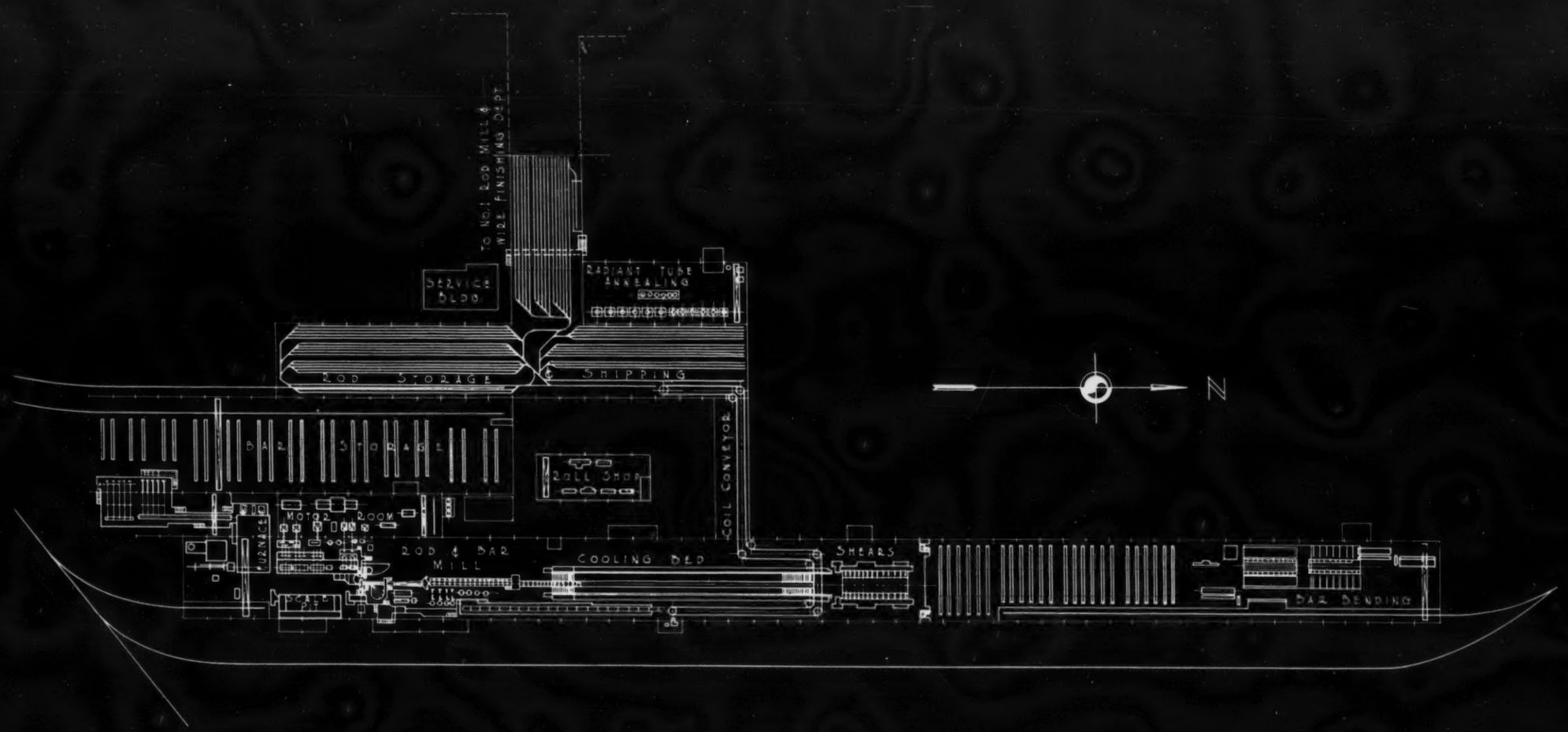
Exterior view of building which houses the four pipe mills. These units have an annual capacity of 216,000 gross tons.

cause-way. At this same place are located the pipe mills, of which there are four:

One butt-weld mill for pipe ¼″ to 2″ in diameter.
One butt-weld mill for pipe 1½″ to 3″ in diameter.
One lap-weld mill for pipe 2″ to 8″ in diameter.
One lap-weld mill for pipe 6″ to 16″ in diameter.

These mills have an annual capacity of 216,000 gross tons. Auxiliary equipment includes galvanizing units, equipment for the production of double length pipe, threading and testing facilities, etc.

Interior view of pipe mill building. Included here are two butt-weld tube mills and two lap-weld tube mills.



No. 2 ROD & BAR MILL

Maryland Plant

BETHLEHEM STEEL COMPANY

Sparrows Point, Md.

View of yard for storing billets prior to their being conveyed to the heating furnace and subsequent rolling.

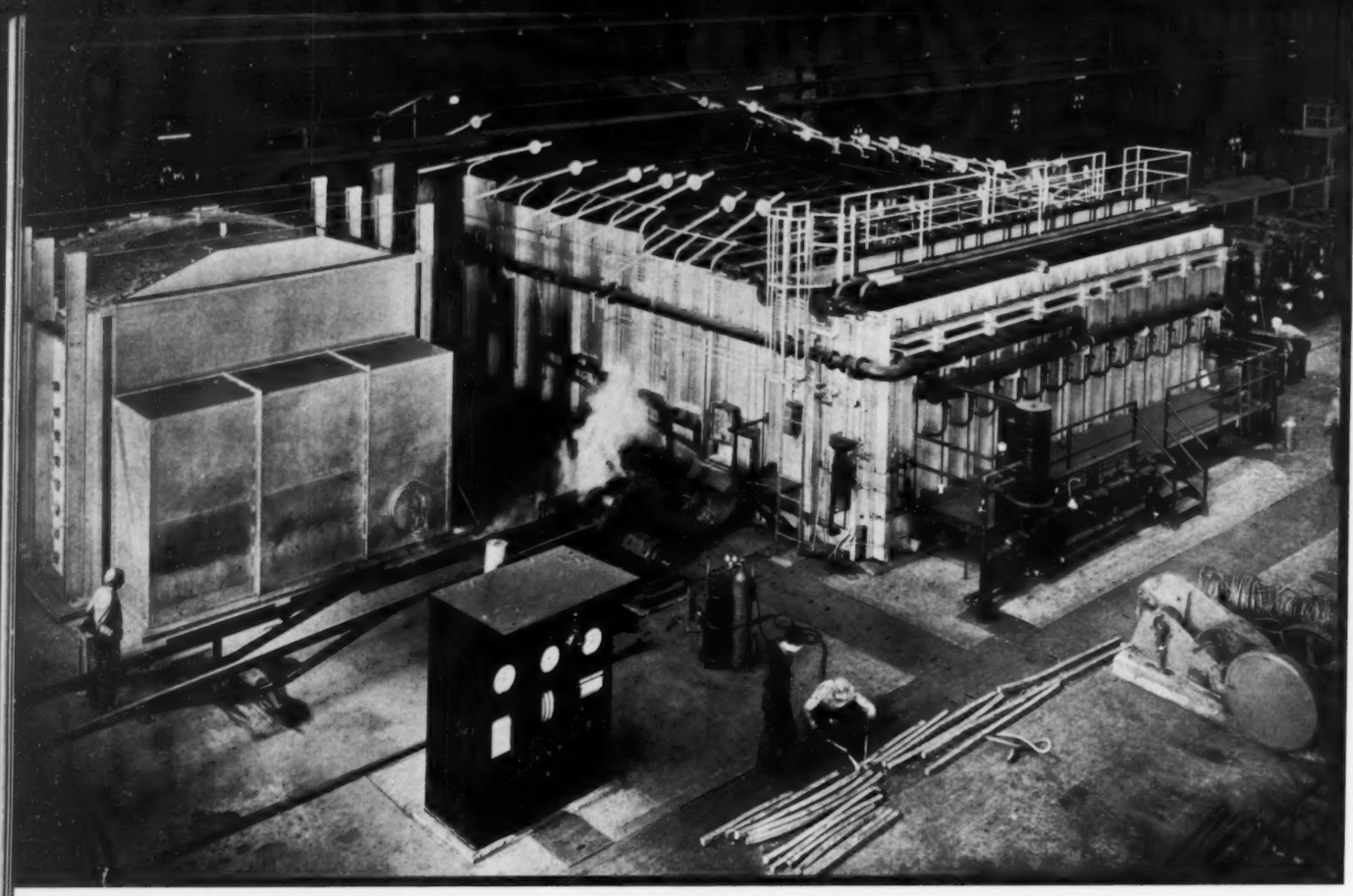
ROD MILLS

A portion of the production of the Maryland plant is in wire and wire products, and the capacity for this type of product has recently been increased. The desire for high quality and tonnage led to the installation of a new 10″ continuous rod mill, incorporating modern developments and improvements. This mill is designed to roll billets of 1 5/16″ to 3″ square into wire rod from No. 5 gauge (.207″ diameter) up to 3/8″ diameter, or into bars 3/8″ to 1″ in diameter.

Billets of 30 ft. length are heated in a single continuous furnace, side charged and discharged. Billets are moved through the furnace by a double crank type pusher, and a pinch roll type pushout discharges them into the mill. The furnace has a hearth 32 ft. wide x 50 ft. long, and is rated at 50 gross tons of 2 1/4″ square billets per hour. The roof is a suspended arch, and the entire furnace is well insulated and encased in steel. A two-pass recuperator serves to preheat air used for combustion to temperatures of 600-700 degrees F. The furnace may be fired with either a gas of 500 Btu. per cu. ft. or with bunker C fuel oil. Thirteen gas burners and twelve oil burners are spaced across the width of the furnace, which is entirely over-fired. The fuel oil is applied through the roof with mechanical atomizers. The furnace is operated automatically from roof temperature, with ratio controls of air to fuel. Automatic furnace pressure is also provided, and a radiation pyrometer furnishes a check on heating temperatures.

The mill is a combination rod and bar mill, designed for eventually handling four strands at a time through

Chain transfer which transports the billets from power operated skids to the heating furnace charging conveyor.



Overhead view of continuous furnace for heating billets of 30 feet length. This furnace with a hearth of 32′ wide x 50′ long has a capacity of 50 gross tons per hour.

the rolls, although at present only two strands can be handled since there is but one finishing train installed. The mill is composed of nine roughing stands, four intermediate roughing stands, two looping stands and six finishing stands. The roughers are driven by three motors, as follows:

No. 0 and No. 1 stands driven through gears by one 500 HP., 250/750 RPM., 600 volt D.C. shunt motor.

No. 2 stand driven through gears by one 300 HP. motor of the same characteristics.

Nos. 3, 4, 5, 6, 7 and 8 stands driven through gears by one 1500 HP., 150/450 RPM. motor, also 600 volts DC. shunt wound.

The intermediate roughers are driven as follows:

No. 9 and No. 10 stands driven by one 700 HP., 300/900 RPM., 600 volt DC. shunt motor.

No. 11 and No. 12 stands driven by a 700 HP., 225/625 RPM. motor of the same characteristics.

The looping stands employ the following drives:

No. 13 stand. One 700 HP., 225/625 RPM., 600 volt DC. shunt motor.

No. 14 stand by a similar motor but of 300/625 RPM.

The finishing train, consisting of six stands, is driven through gears by one 1250 HP., 500/750 RPM., 600 volts DC. shunt motor. A maximum delivery speed of approximately 4100 ft. per minute, leaving the last finishing stand, may be obtained. Future plans call for the installation of another finishing train duplicating the present one.

The mill motors are operated from three 1750 KW., 450/600 volt DC. generators, one for the first three mill motors together, and two in parallel for the remaining motors. These three generators, together with one 1500 KW., 250 volt DC. generator and a 100 KW. exciter, go to form a motor-generator set, all driven by one 8200 KVA., 6600 volt, 60 cycle, 1.0 P.F., 514 RPM. synchronous motor. The 1500 KW. generator supplies the 250 volt mill power, and the exciter serves the synchronous motor, the 600 volt generators and the mill motors. The M.G. set is located in the motor room, which also contains the first six main drive motors, a 199/597 volt variable frequency M.G. set, the 6600 volt metal clad switchgear, a duplex board for metering and controlling the A.C. and D.C. circuits, and control boards for the 440 volt A.C. and 250 volt D.C. feeder circuits. Space is also provided for future equipment.

The basement of the motor room contains D.C. switching equipment, generator and motor field rheostats, and ventilating equipment. This latter equipment includes two 37,000 c.f.m. fans which draw air through the generators through air coolers and into the basement, from where it passes up through the mill motors and into the motor room, making, in effect a down-draft system for the generators, with the mill motors placed in the path of the return air. Ventilation of the synchronous motor driving the M.G. set is effected by fan blades on its rotating field spider, which circulate air through a cooler placed in a duct under the foundation, from where it returns to the motor.

The last two main drive motors are located in the mill building proper, and are provided with enclosing covers. They are ventilated by a closed air system, with fan and fin type air cooler.

The mill is controlled from the operating pulpit, where there is located a desk board with switches for controlling armature and field circuits of the generators and mill motors, and of the DC. drive motor of the variable frequency M.G. set. There are ammeters for the generators and mill motors, voltmeters for the gen-

erators, and tachometers for all mill motors and for the variable frequency set. The desk also includes lever operated vernier field rheostats for the last five motors.

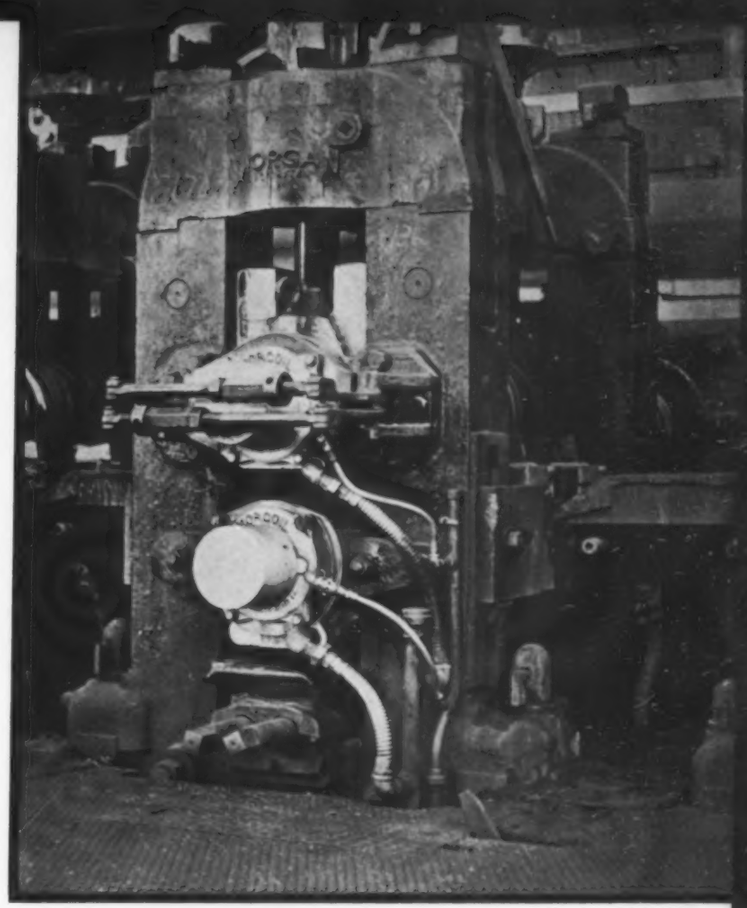
Near No. 1 stand in the mill is a control cabinet with meters and control switches for operating the motor-driven coarse and vernier field rheostat, to give individual speed control of the first three main motors. The pulpit operator controls the speed of these three motors as a group, thereby controlling the loop formed between stands No. 8 and No. 9.

All motors employ special series compounding exciters for maintaining a speed regulation of not more than 1½% from friction load to full load.

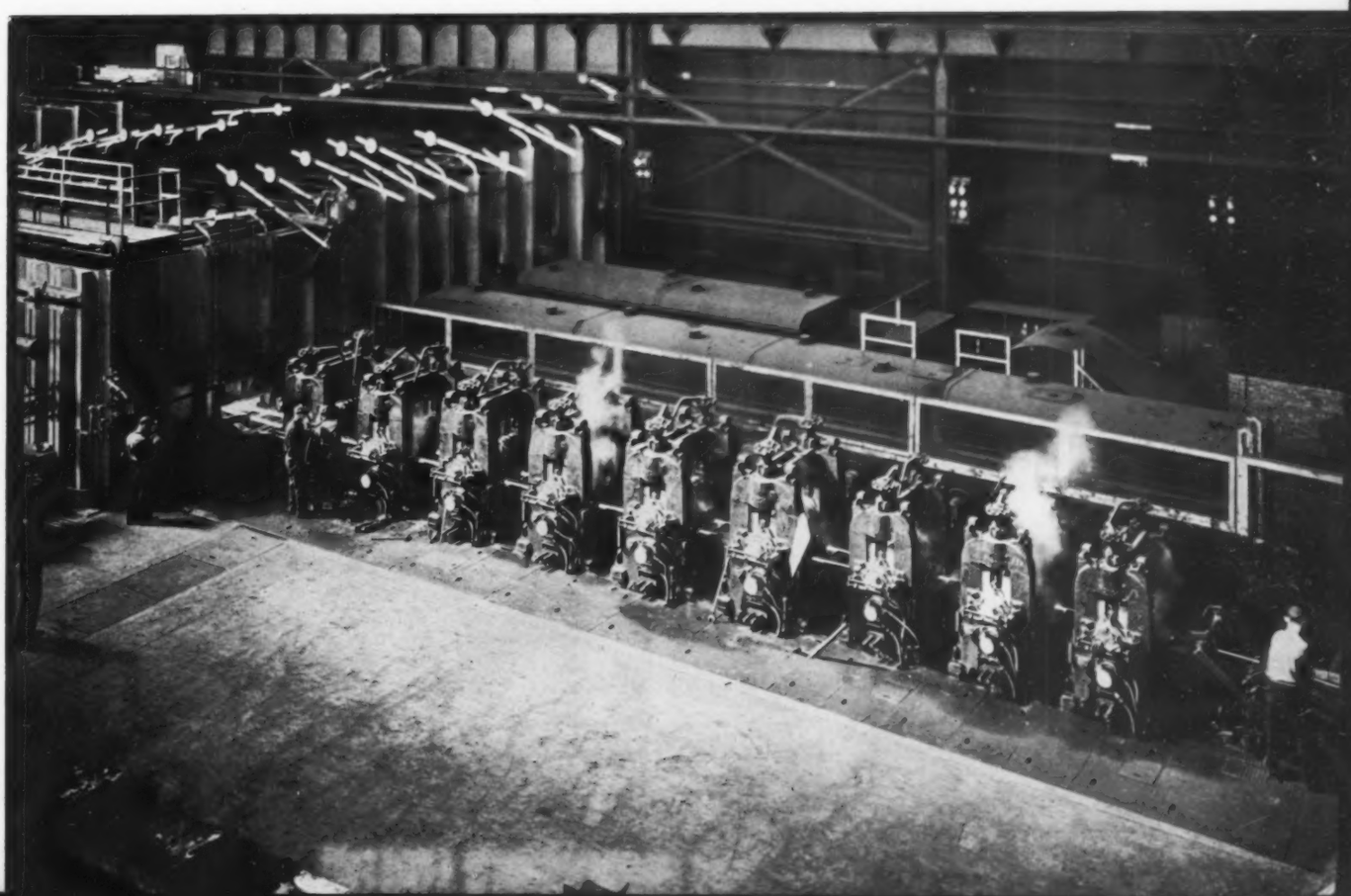
By means of motor operated potentiometer type field rheostats the voltage of the generators can be adjusted from 600 to 450 volts to secure reduced speed. One such rheostat is provided for generator No. 1, and one for generators No. 2 and No. 3 in parallel. Voltage regulators mounted in the duplex board previously mentioned maintain voltage at the desired setting, so that constant voltage conditions help maintain fixed speeds on the motors during normal operating conditions. In case of emergency, a tie can be closed between the two generator buses, so that generator No. 1 can be paralleled with either No. 2 or No. 3, if one of these is out of order.

Mill output depends primarily on the size of product, ranging from 20 to 50 tons per hour.

The billet is reduced through the mill in alternate square and oval passes. Twist guides turn the piece 45 degrees after each square pass and 90 degrees after each oval pass. Roll adjustments are made by top



In the above picture is shown a close-up of one of the stands in the roughing train. All stands are equipped with oil flooded bearings and special features for groove pass alignment.



Discharge end of the heating furnace and the nine roughing stands are shown in this illustration. The capacity of this mill, depending on size of product, is from 20 to 50 tons per hour.

Following the nine stands in the roughing train is shown four intermediate roughing stands and the two looping stands. Following these are the six finishing stands.

View of operating pulpit for controlling the mill. Included in this pulpit are ammeters for the generators and mill motors, voltmeters for the generators and tachometers for all mill motors.

screws and bottom wedges. Side adjustments are made on the top rolls by means of end screws.

Oil flooded bearings are used for all roll necks, for which lubrication is provided by two oiling systems. A 2000 gallon system, using an oil of 1750 sec. viscosity at 100 degrees F., serves the roughing stands, and a 7000 gallon system supplies the finishing stands with an oil of 300 sec. viscosity at 100 degrees F.

Mill pinions are made of forged steel, with cut, case-hardened helical teeth, and run in babbit bearings. Gear drives are herringbone and helical cut cast steel gears and forged steel pinions, and run in babbitt split bushings. Lubrication for this equipment is furnished from a 6000 gallon oil system using 1750 sec. viscosity at 100 degrees F. oil for the roughers, and on 8000 gallon system using 550 viscosity oil for the finishers.

All bearings and drive oil systems are equipped with automatic signals indicating failure of oil pressure, and the furnace pusher is interlocked so as to prevent further operation until oil pressure is restored. On starting up, main drive motors cannot be started until oil pressure has been established.

A unique scale pit for catching return water from the mill and settling out mill scale is used here. This water is then pumped to a cooling tower and again allowed to settle, from where it is used for reel and roll cooling in a continuous recirculation.

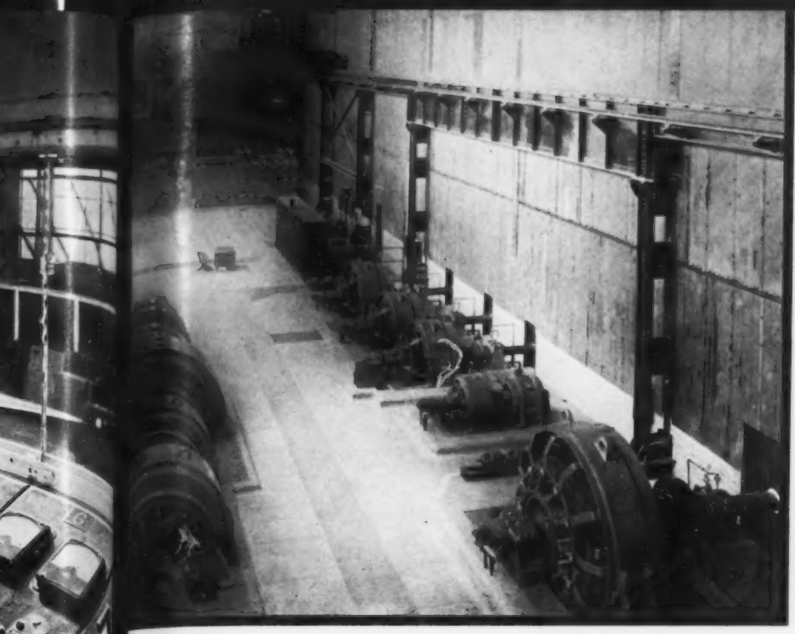
When rolling heavier sizes, the finishing train is not used. The delivery speed from stand No. 14 varies from 650 to 1800 ft. per min., while the speed of the runout table rollers for merchant bars is one-third higher. These runout tables are driven by eighty-one .78 HP. and thirty-two 1.38 HP. direct connected squirrel-cage motors, which are operated by the adjustable frequency motor-generator set previously mentioned. Table rollers are cylindrical and cone type, and run in ball bearings.

The finishing mill motor can be started and stopped independently of the preceding stands, being provided with a magnetic starting panel.

Four automatic laying reels receive light rods, forming coils of 34″ inside diameter and 46″ outside diameter. These reels are driven by one adjustable speed motor which receives power from a generator direct-connected to the finishing train motor. Two pouring reels for heavy rod are each driven by an individual adjustable speed motor which receives power from a generator directly connected to the motor driving No. 14 mill stand. Water sprays are placed ahead of the reels, using water which has been passed through the air coolers on the electrical equipment.

Other auxiliary equipment includes a steam operated 4-way switch plate and a manually operated toggle shear at the entering end of the mill; one steam 4-strand flying shear between No. 8 and No. 9 stands; 4-strand repeaters serving No. 13 and No. 14 looping stands; an electrically operated 4-strand snap shear mounted on the entering side of No. 14 stand; two rotary bar

This double cooling bed and run out table is 360 feet in length. In the background is shown the rod coil conveyor and hook carrier.



General view of rod mill motor room from roughing end. This room houses the first six main drive motors, variable frequency M. G. set and the 6600 volt metal clad switchgear, as well as the various control boards.

shears controlled from flag switches mounted on the cooling bed; a 270 ft. double carryover cooling bed; a coil conveyor.

Miscellaneous equipment further includes one large guide grinder; two small guide grinders; scrap shears; cobble bundlers; bar shears; three bar benders; three 18″ roll lathes; three 26″ roll lathes; one 16″ x 96″ grinder; a profile cutting machine.

The installation of this mill required the expansion of wire drawing and finishing equipment. Twenty-nine wire drawing frames, of various sizes, were installed, thereby adding 10–16 tons per hour to the previous capacity. The dry process is used in drawing, the wire being first cleaned in sulphuric acid and hot water dip tanks in a straight line process, then passing through lime dip tanks and continuous lime bakers. Wire is

Four automatic laying reels receive light rod, forming coils of 34″ inside diameter and 46″ outside diameter. These reels are driven by one adjustable speed motor.

Heat treating equipment for this rod mill includes four radiant tube type wire annealing covers using recirculating fans.

After being coiled on the laying reels, the rod is transported by this conveyor into the processing and finishing departments.

Additional equipment necessary upon the installation of this new rod mill is the above roll shop for keeping the rolls in the proper shape.

produced in sizes ranging from No. 20 up to 11/16" diameter. Finished wire size is usually 60–70% of the rod size. Heat treating equipment has also been increased by the installation of four radiant tube type wire annealing covers, with twelve bases, using recirculating fans, and one patent annealing furnace, with feed reels and take-up frames. Two 1500 cu. ft. per hour gas atmosphere machines were also installed.

The No. 1 Rod Mill consists of seven 12" roughing stands and ten 10" finishing stands, all driven through gears by a single 4000 HP., 6600 volt, 375 RPM., 25 cycle motor. Roughing rolls are 12¾" diameter x 19½" body length and run in babbitted bearings. Finishing rolls are 10" x 18". Babbitt bearings are hand packed with grease. All gears, pinions, and gear reductions are lubricated with 550 second viscosity at 100 degrees engine oil in a circulating system.

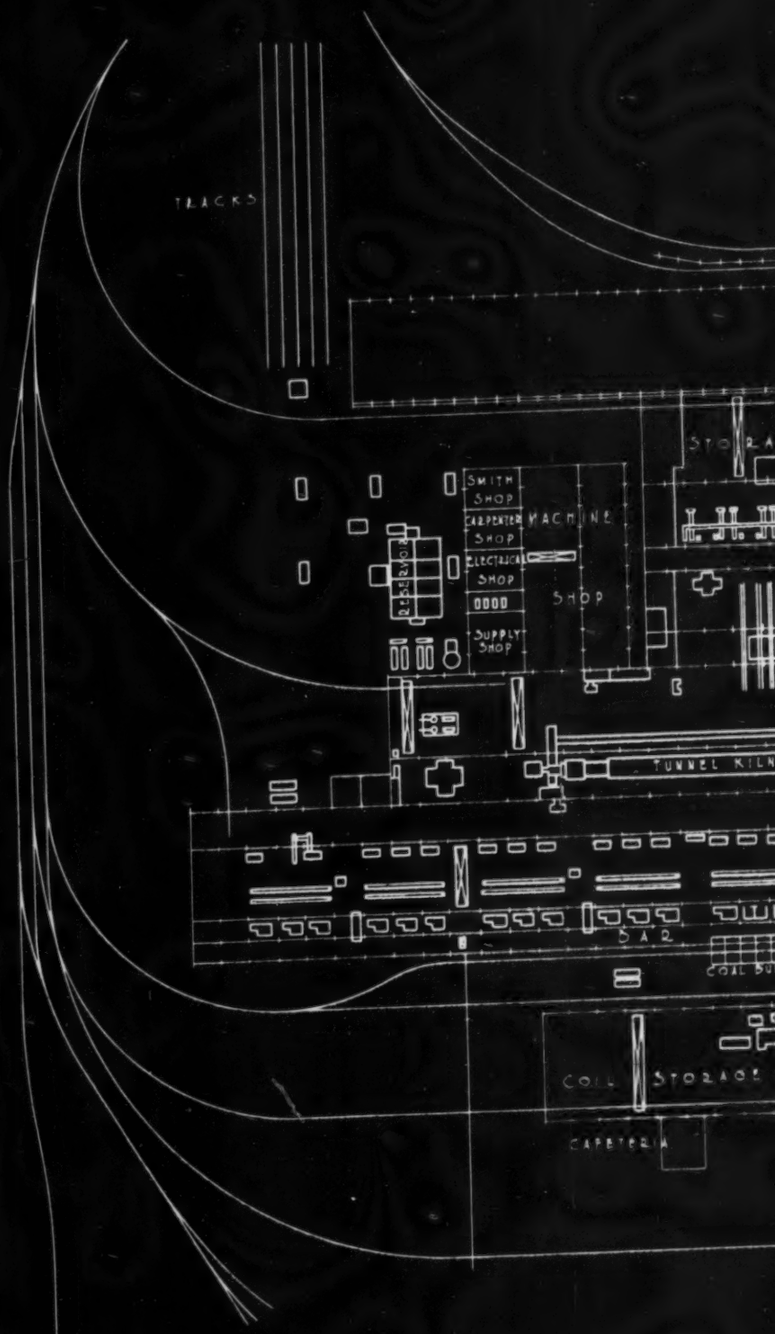
Capacity of this mill is 20 tons per hour.

Billets come to this mill in sizes 1 15/16" square to 2" square, and are rolled down to rods ranging from No. 5 rod to ½" diameter, all coiled. Reductions in each pass run from 10% to 34%. Delivery speed from this mill is about 3125 ft. per min.

Heating facilities consist of a single continuous billet heating furnace, with a 25' x 30' hearth. Steel temperature is recorded by a radiation pyrometer.

Finishing equipment previous to the new expansion consisted of 4 continuous patenting units for processing high-carbon wire, 109 single die wire-drawing blocks and 76 dual type blocks, all individually driven, 9 continuous multiple blocks, 145 nail machines, 17 barbed wire machines, 8 bale-tie machines, 5 wire straightening and cutting machines, 2 wire galvanizing units, and 2 Bethanizing units. The last named operation was developed in this plant, and consists of a continuous electrolytic process in which a heavy durable coating of pure zinc is deposited on the wire. It produces a coating that will withstand severe bending and forming operations without damage.

General view of the roughing stands of the original No. 1 rod mill, which includes seven roughing stands and ten finishing stands. Its capacity is 20 tons per hour.


TRACKS
SMITH SHOP
CARPENTER SHOP
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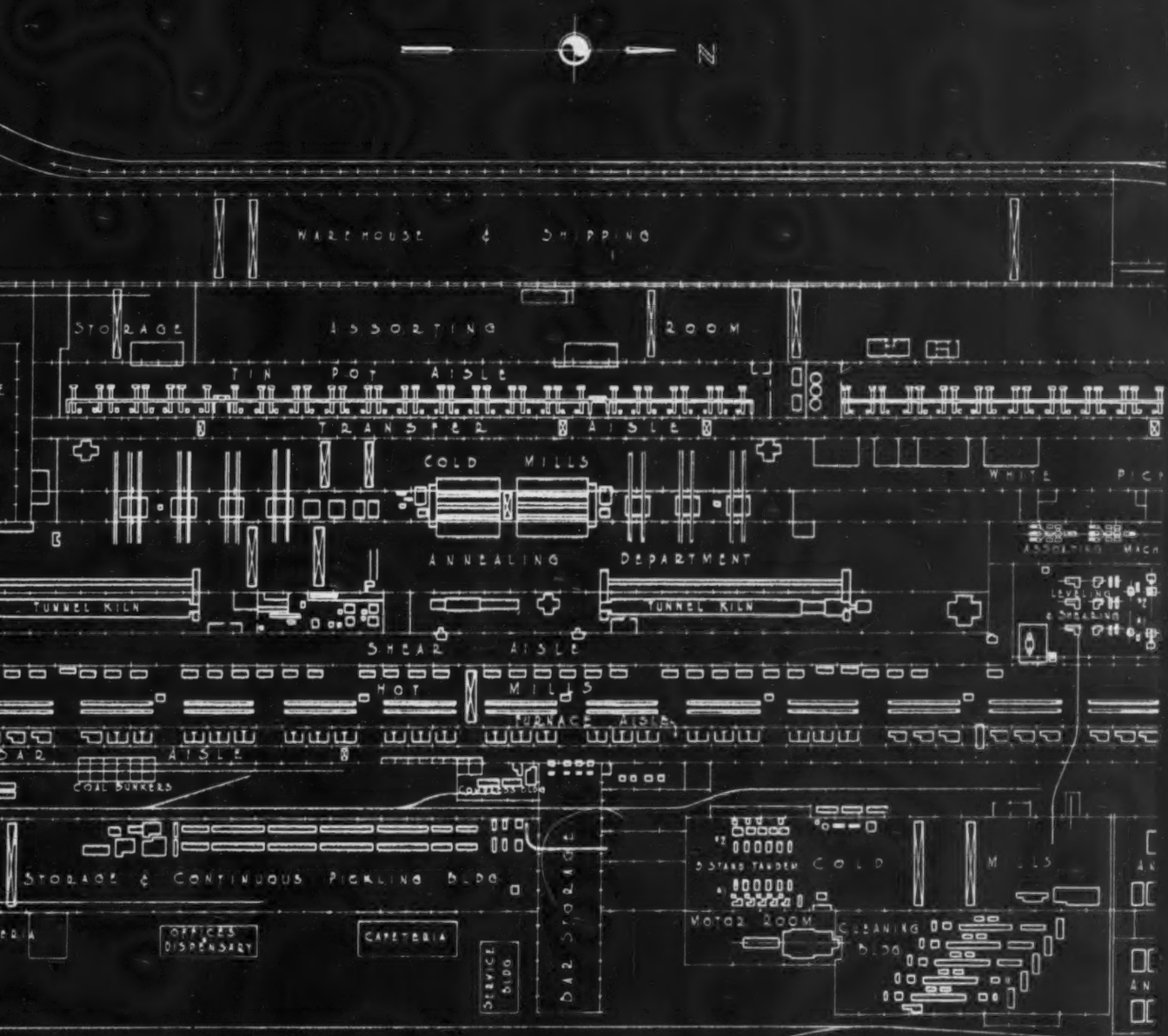
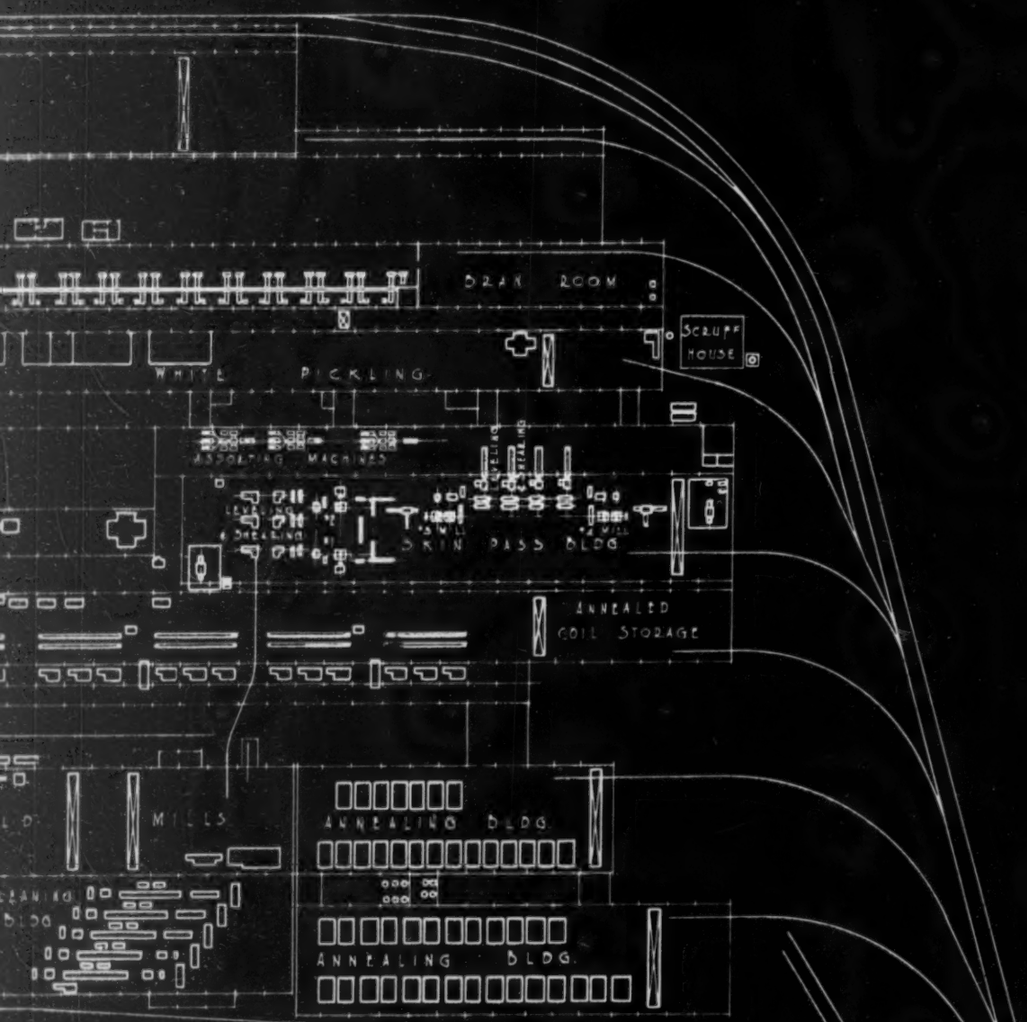
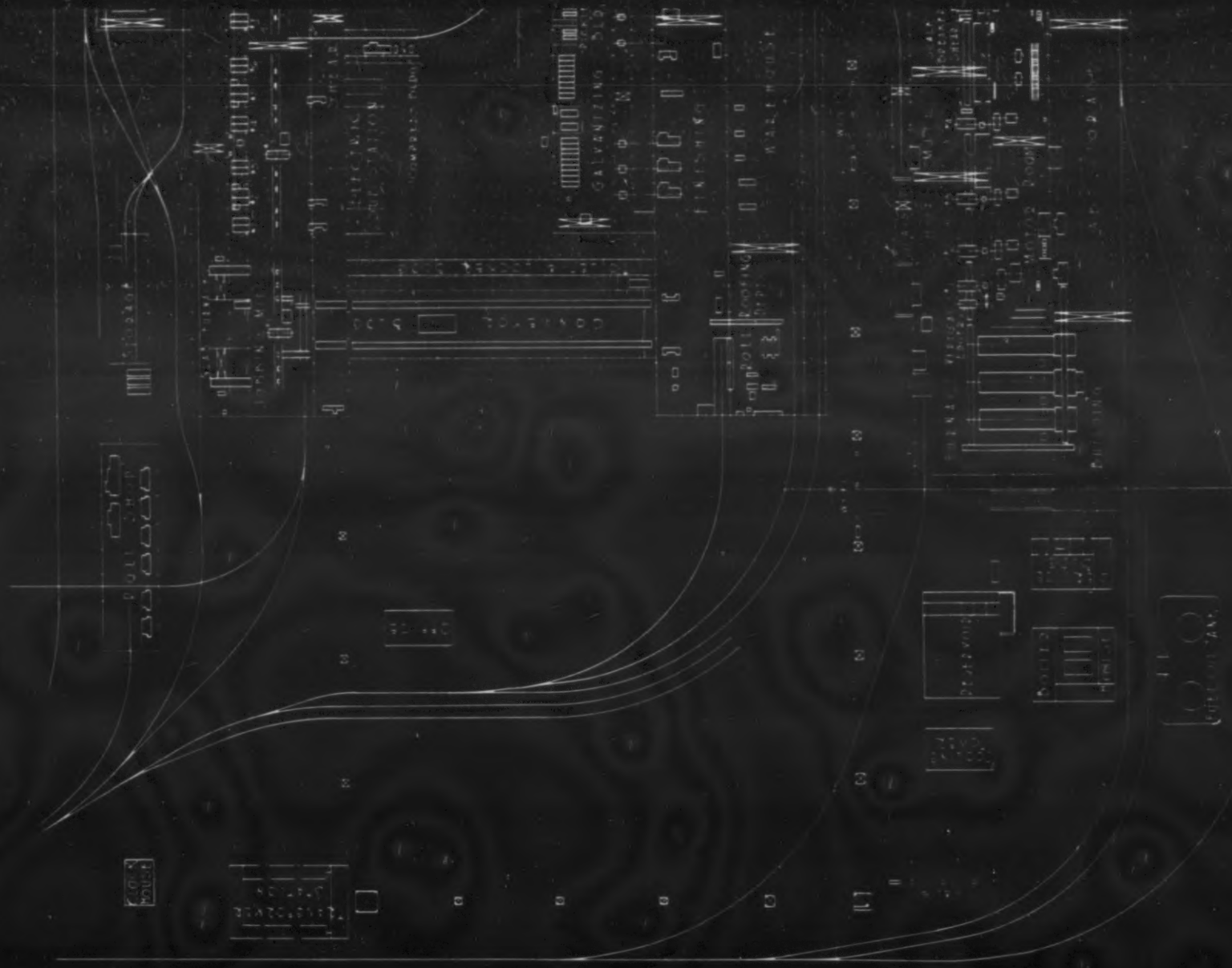
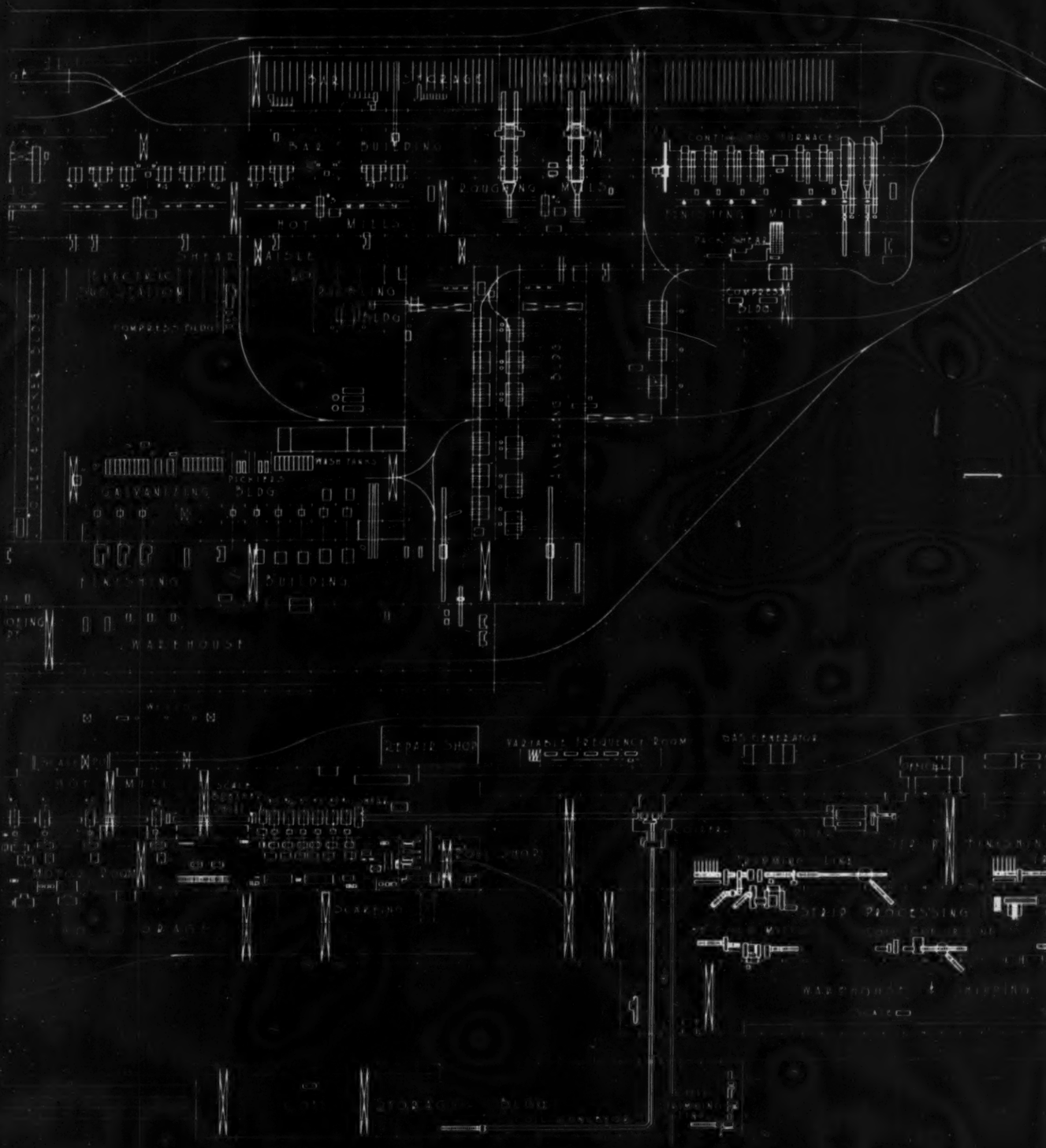
0000
SUPPLY SHOP
MACHINE SHOP
TUNNEL KILN
BAR
COIL STORAGE
CAFETERIA



HOT AND COLD TIN MILLS
MARYLAND PLANT
BETHLEHEM STEEL COMPANY
SPARROWS POINT, MARYLAND


DRAW ROOM
SCRUFF HOUSE
WHITE PICKLING
ANNEALED COIL STORAGE
MILLS
ANNEALING BLDG.
ANNEALING BLDG.



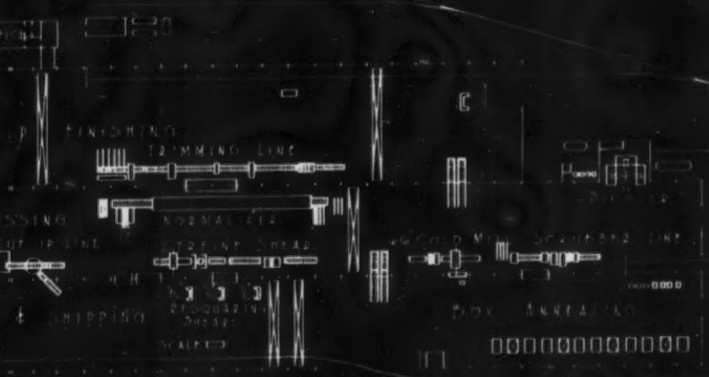


56" HOT STRIP MILL AND SHEET MILLS

MARYLAND PLANT

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MARYLAND


FINISHING
TRIMMING LINE
NORMALIZE
BOX ANNEALING

Slab storage yard with a capacity of about 15,000 tons. After scarfing, cranes place the slabs on a magazine feeder for moving to the furnace charging table.

be rolled. Slabs, ranging 14″ to 50″ in widths, 5′–6″ to 16′–0″ in length, 4½″ to 5½″ in thickness, and 1100 lbs.–11,000 lbs. in weight, are supplied to the mill from the slabbing and blooming mills in the steel plant.

A summary of building going to make up this mill unit, with their dimensions and crane data is as follows:

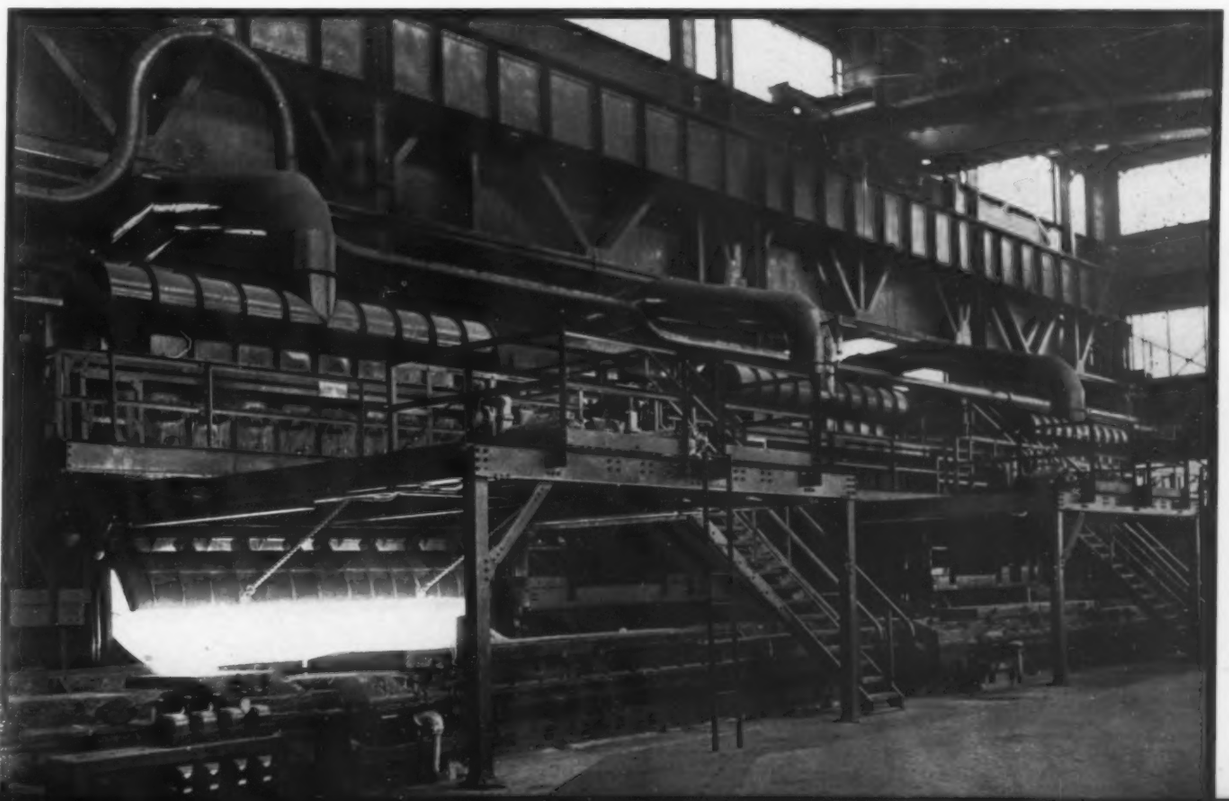
	Buildings		Cranes		
	Lgth.	Width	Number	Capacity —Tons	Approx. Span.
Slab Storage	825′	90′–2″	3	25/10	85′
Furnace Building	160′	65′–2″	.....	.....	.....
Hot Mill Building	785′	87′–8″	2	60/20	82′–6″
Motor Room	525′	65′–2″	1	25	60′
Strip Finishing	1050′	115′–2″	2	25/15	110′
Strip Finishing	1050′	115′–2″	1	25	110′
Strip Processing	1225′	90′–2″	1	25/15	85′
Strip Processing	1225′	90′–2″	2	15	85′
Warehouse and Shipping	825′	90′–2″	2	15	85′
Coil Storage	675′	90′–2″	2	15	85′
Box Anneal Building	225′	90′–2″	1	25/15	85′
Roll Shop	100′	65′–2″	1	50/10	60′
Scale Pit	.....	.....	1	5	16′

The slab yard has a storage capacity of about 15,000 tons. Slabs arrive on specially designed standard gauge cars, which enter on a depressed track running the full length of the yard. Slab scarfing is done on a bed

HOT STRIP MILL

Another unit contributing extensively to the modernization program of this plant is the 56″ Continuous Hot Strip Mill, which lies along the eastern edge of the plant. This mill was constructed in 1937 and placed in operation the latter part of that year. It has a nominal capacity of 50,000 gross tons of strip per month, and is designed to roll strip in widths of 14″–48″ down to a minimum of No. 20 gauge. Sheets up to ¼″ and skelp up to ½″ in thickness may also

View of heated slab being ejected from one of the three continuous triple-zone furnaces. Each of these furnaces has a rated capacity of 50 gross tons of cold steel per hour.



250′ x 40′, located in one corner of the slab yard and serviced by a 7½ ton gantry crane equipped with a double magnet. Slab yard cranes subsequently place the conditioned slabs on a magazine elevator feeder, from whence a chain transfer moves one slab at a time on to the furnace charging table. The magazine feeder is driven by a 35 HP., 575 RPM. motor, and the chain transfer by a 25 HP., 650 RPM. motor, both 230 volts compound. The charging table, which is 162 ft. long, runs along the back ends of the hot mill furnaces and is divided into three sections, each driven by a 50 HP., 550 RPM. DC motor. Double head pushers, of rack and pinion type, which can be operated singly or interlocked, so as to operate as a unit, allow either double or single row charging of the slabs into the furnaces. Pushers are driven, through worm reductions, by 50 HP., 550 RPM. compound motors.

SLAB FURNACES

Slabs for the strip mill are heated in three continuous triple-zone furnaces, each with a rated capacity of 50 gross tons per hour of cold steel to a rolling temperature averaging 2250 degrees F. Hearth dimensions are 18 ft. in width x 80 ft. in length, 16′–9″ of which is a solid hearth soaking zone. The fuel used is bunker C fuel oil, which is fired in the heating zone through six burners above the steel and six burners below the steel, spaced evenly across the width of the furnace. The soaking zone is overfired by eight similar burners. All of these burners are steam-atomizing, and have a total capacity of 700 gal. per hour for each furnace.

Each furnace is provided with two tile recuperators capable of heating air for combustion to a temperature of 600-700 degrees F. The air is pulled through the recuperators by fans of 37,500 cu. ft. per min. capacity of 600 degrees F. Furnaces are completely insulated and steel encased. Flat suspended roofs are used.

Instruments and controls on these furnaces present a very complete layout. Each separate firing zone is supplied with an automatic fuel-air ratio control as well as an oil flowmeter. Furnace pressure is automatically controlled as is temperature of air to the burners. Each furnace also has a recording potentiometer on temperatures of gases before and after the recuperator, steam and oil pressure gauges for each zone, and a recording draft gauge.

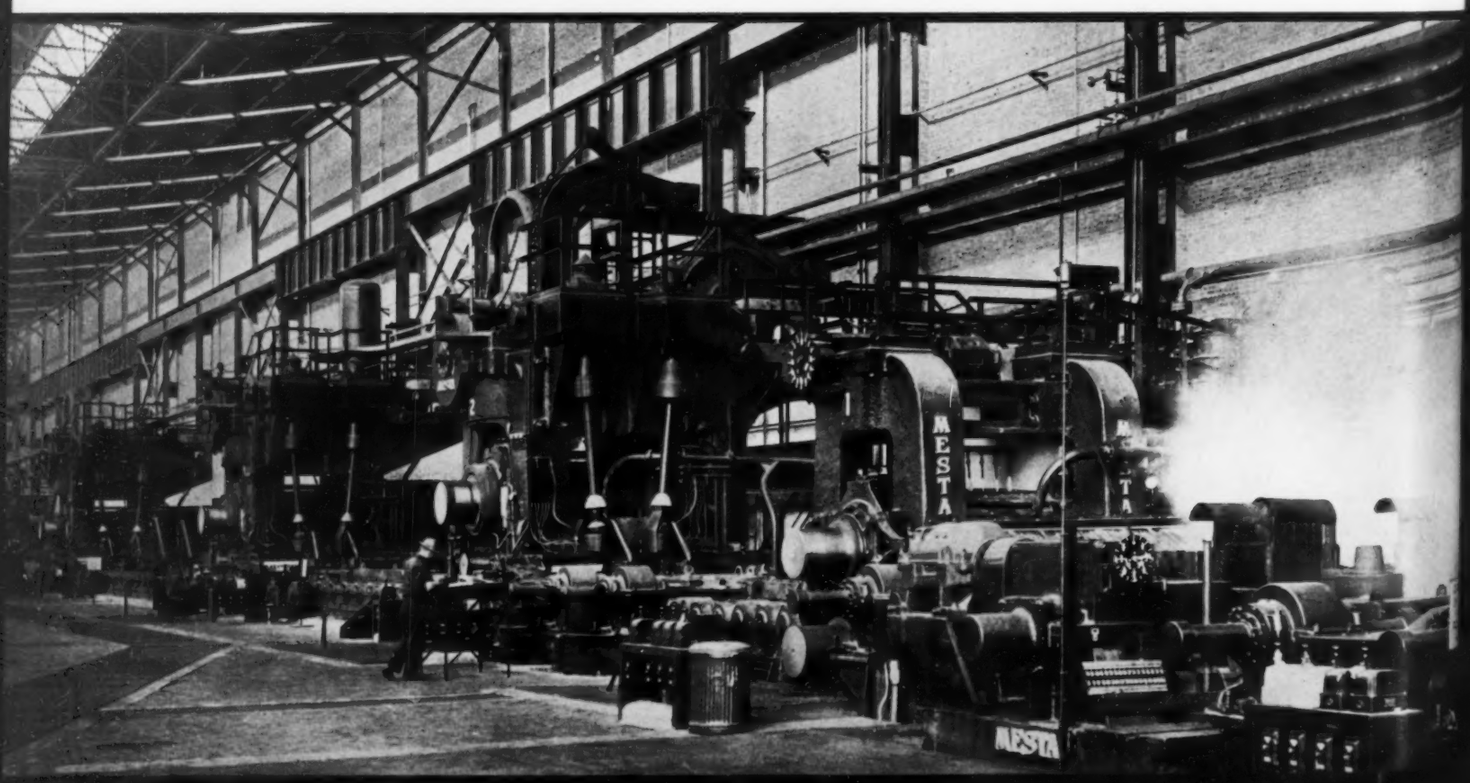
The furnaces operate at an average rate of about 57 lb. of steel per hour per sq. ft. of hearth area.

HOT MILL

A roller table, 140 ft. long, receives slabs from the furnaces and conveys them to the hot mill.

The first unit of the mill is a vertical edger of the overhung type, driven by two 300 HP., 514 RPM., 440 volt induction motors, the mill efficiently serving to crack loose furnace scale, which is then removed by hydraulic sprays. Two 50 HP., 500 RPM., 230 volt DC. series motors serve for roll adjustment in this edger. Next comes the first roughing mill, a 2-high stand, 36″ x 56″, driven by a 3000 HP., 6600 volt, 144 RPM. synchronous motor, followed by three more roughers. These are 4-high stands, with work rolls 25″ x 58″, and backup rolls 49″ x 54″. Each stand is driven by a motor of similar characteristics as the previous stand, but of 360 RPM. These motors are controlled by the operator in the roughing pulpit. They are cross-the-line type, and are started and stopped directly by means of the oil circuit breakers in the main metal clad units. The roughing stands are spaced 36′–9″, 55′–6″ and 82′–6″ apart respectively. The last three roughing stands are provided with integral edging rolls 22″ in diameter, with a 14″–48″ adjustment range. Each edger is driven by a single 150 HP., 450/900 RPM., 230 volt shunt motor mounted on top of the mill housing. Adjustment is effected through a 15 HP., 650 RPM., 230 volt series motor.

After the slab has been heated to the proper rolling temperature in the heating furnaces, it is conveyed to the hot mill roughing train. The hot mill roughing trains stands are shown in the lower illustration.



Between the roughing and finishing stands is a roller table which serves as a temperature control point. The recording radiation pyrometer seen keeps continuous records of strip temperature at this point.

A roller table, about 145 ft. long, separates the roughing train from the finishing train, and serves as a temperature control table, being equipped with water sprays. A recording radiation pyrometer, which can be read at the hot mill furnaces, keeps continuous record of strip temperatures at this point, and operates a system of signal lights at the furnace and at the finishing train, indicating accuracy of temperature.

Two rotary crop shears are also located along this table, one just after the last roughing stand and another just ahead of the finishing train. These shears crop in opposite directions and are used to remove defective ends on strip before it is finished. A 75 HP. compound motor drives each shear.

The finishing train is composed of a scale breaker and six finishing stands. The former is a 2-high 24″ x 56″ stand, driven by a 500 HP., 150/600 RPM., 600 volt DC. motor. The finishing stands, which are spaced on 18 ft. centers, are all 4-high, with 24″ x 58″ work rolls and 40″ x 54″ back-up rolls. Each stand is driven through gears by a 3000 HP., 600 volt DC. motor, the first five of 200/400 RPM., and the last of 175/350 RPM. These motors are controlled by the operators in the finishing pulpit.

Speed of strip through the mill is as follows:

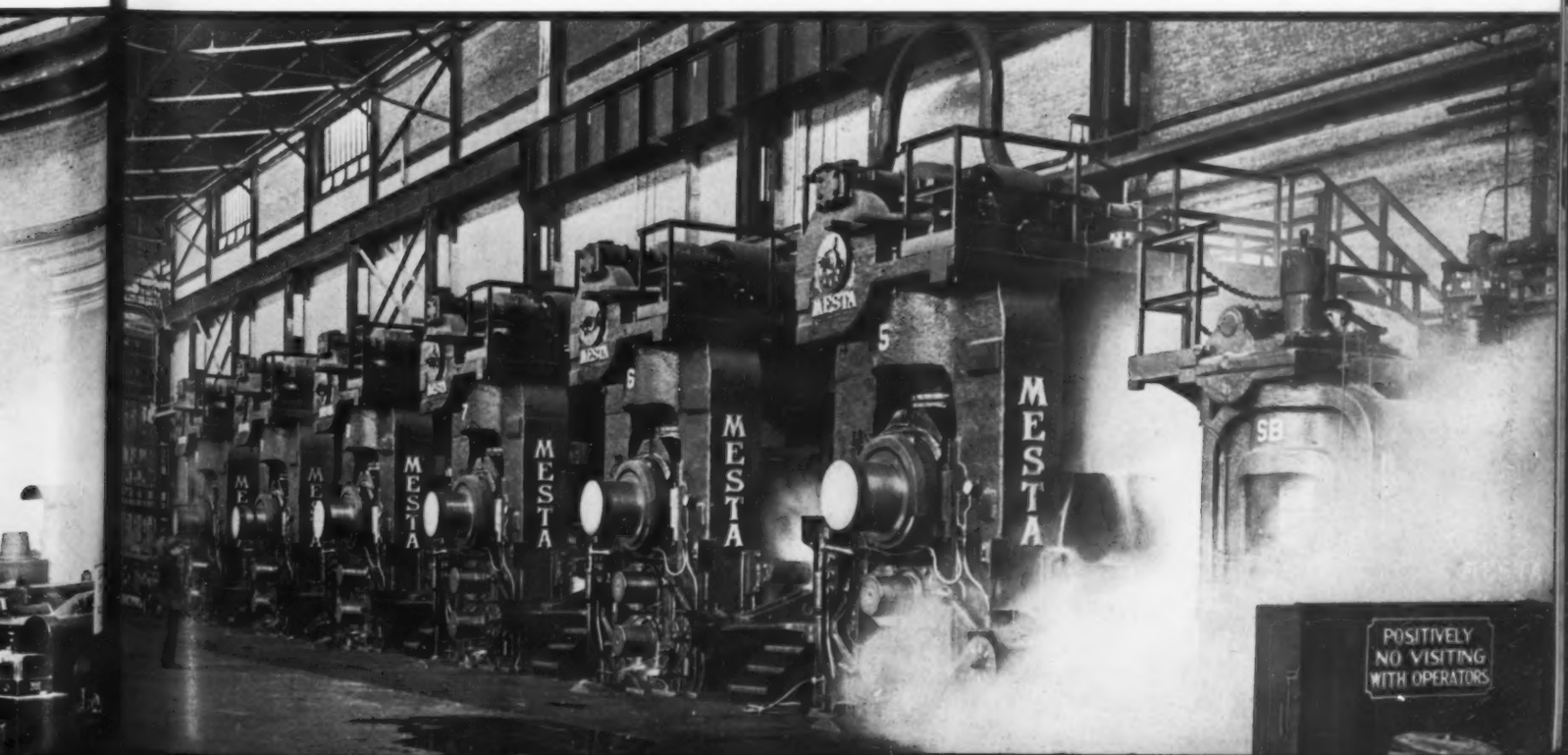
No. 1 Rougher	170.9	ft. per min.
No. 2 Rougher	281.2	ft. per min.
No. 3 Rougher	399.3	ft. per min.
No. 4 Rougher	399.3	ft. per min.
No. 2 Scalebreaker	107 /428	ft. per min.
No. 5 Finisher	222.5/445	ft. per min.
No. 6 Finisher	385 /769	ft. per min.
No. 7 Finisher	556 /1111	ft. per min.
No. 8 Finisher	733.5/1467	ft. per min.
No. 9 Finisher	867 /1734	ft. per min.
No. 10 Finisher	983.5/1967	ft. per min.

A second radiation pyrometer records temperature of the strip as it leaves the last finishing stand.

Screwdowns on each of the 4-high stands are driven by two 50 HP., 550 RPM., 230 volt compound motors. Combined or individual operation of the mill screws is provided for by a magnetic clutch which ties the two drives together. The 2-high rougher screwdown is driven by a single 35 HP., 575 RPM., 230 volt compound motor, and that of the scale breaker by a 15 HP., 725 RPM., compound motor.

All 4-high stands have roller bearings on the work rolls and the oil-flooded sleeve bearings on the backup

The finishing train of this new 56″ continuous hot strip mill is composed of a scale breaker and six finishing stands. Its maximum delivery speed is 1967 feet per minute.



rolls. Oil-flooded bearings are also applied to the 2-high rougher, while the vertical edger uses roller bearings.

Five loopers, one between each finishing stand, serve to take up slack in the strip as it passes through the train. Each is powered by a 50 HP., 550 RPM. shunt motor, controlled manually from the speed control pulpit.

Hydraulic descaling sprays, insuring good surface on the finished strip, are located ahead of No. 1, No. 2 and No. 4 roughers, and a double spray is placed between No. 2 scalebreaker and No. 5 finisher. Water is supplied at 1000 lb. pressure to these sprays from two 1200 g.p.m. centrifugal pumps, each driven direct by a 1000 HP. induction motor at 3600 RPM.

A rather unusual water reclamation system is used on this mill, due to the large quantities required, and to the fact that suitable water must be obtained from artesian wells. Nine 650 G.P.M. deep well pumps supply water, which is aerated, treated with lime and a coagulant, and allowed to settle. This water is then pumped through air coolers on the electrical and oil coolers on mill equipment, then through the skid-pipes in the heating furnaces, and is next used in the descaling pumps. This water, together with all water used on the mill rolls flows to a two-way scale recovery and settling pit, where the low uniform velocity of four ft. per min. allows most of the scale to settle out. From here, the water is pumped over a cooling tower, below which settling at a velocity of .9 ft. per min. renders the water quite clean. It is then used on the mill rolls and the coilers. Thus, a recirculating system is effected, from which the only loss is the water used on the coilers. Water in this system is maintained clean, cool, slightly alkaline, and free from scale-forming material.

All roller tables up to the last finishing stand are supplied with roller bearings and are driven through line shafts by 35 HP., 525 RPM. series motors. Beyond the last finishing stand, a runout table, 334′–6″ long, leads to the coilers. This table is composed of 224 rollers, 12″ in diameter x 66″ long, spaced on 18″ centers. The rollers are driven individually by 10-pole induction motors, rated 3-10 HP., 240-720 RPM., 147-440 volts. Beyond the coilers is the piler approach table, 217′–8″ long, composed of 140 rollers driven in pairs through twin gears by 70 four-pole induction motors rated 3-10 H.P., 600-1800 RPM., 147-440 volts. About 100 feet of runout table is provided with water sprays, which can be used to obtain certain metallurgical requirements.

Closely following the last finishing stand is a flying shear, which will cut sections up to ½″ thick x 48″ wide in a length range of 11–30 feet. This shear is driven by two 150 HP., 450-900 RPM., 230 volt shunt motors, and the pinch rolls by a 22 HP., 375/700 RPM. compound motor.

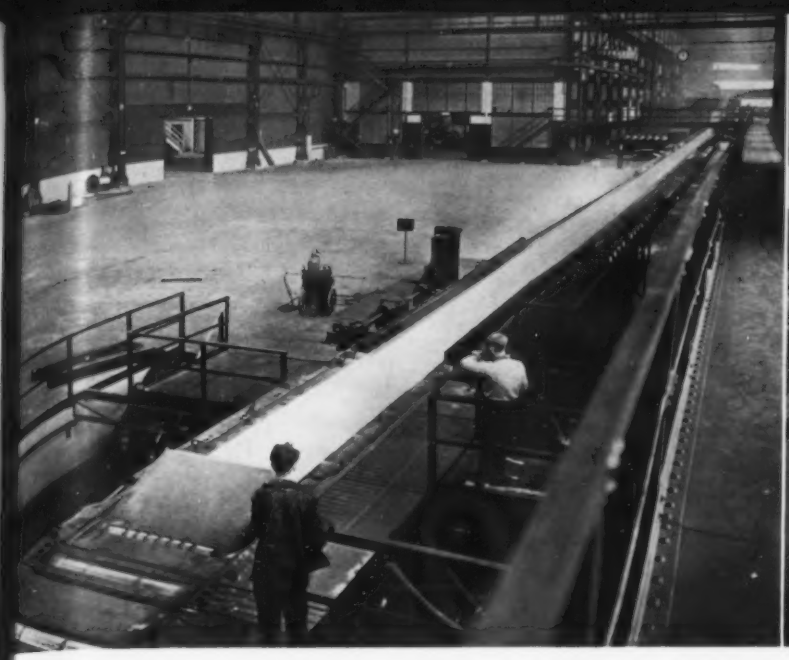
Two coilers are placed in the runout table about 340 ft. beyond the last finisher. Motors on the coiler include the following:

Eight—5-10 HP., 400-1200 RPM., 147-440 volt, 20-60 cycle, 6 pole induction motors for roll drives.
Two —Motors, same as above, for guide roller drive.
Two —Motors of same characteristics, but of 10-20 HP., for pinch roll drive.

Coils are moved from the coiler by air operated ejectors and are deposited on a coil transfer car which moves them to the conveyor, which in turn carries them for a distance of about 330 ft. into the coil storage building. This building also houses a coil trimming line.

A synchronized transmitting system, made up of one unit located at No. 10 finisher, one unit at the pilers, one unit at the coiler approach, and one unit in the

Panoramic view of entire mill from the heating furnaces, to the roughing train, temperature control table, finishing stands and finally the run-out table.



View of the strip as it leaves the finishing stands and coming down the 340 foot run-out table. It also shows the strip entering the coilers.

Side view of the two coilers showing a coil after being ejected. In turn the coil is placed on a conveyor to be transported to the coil storage building for further processing.

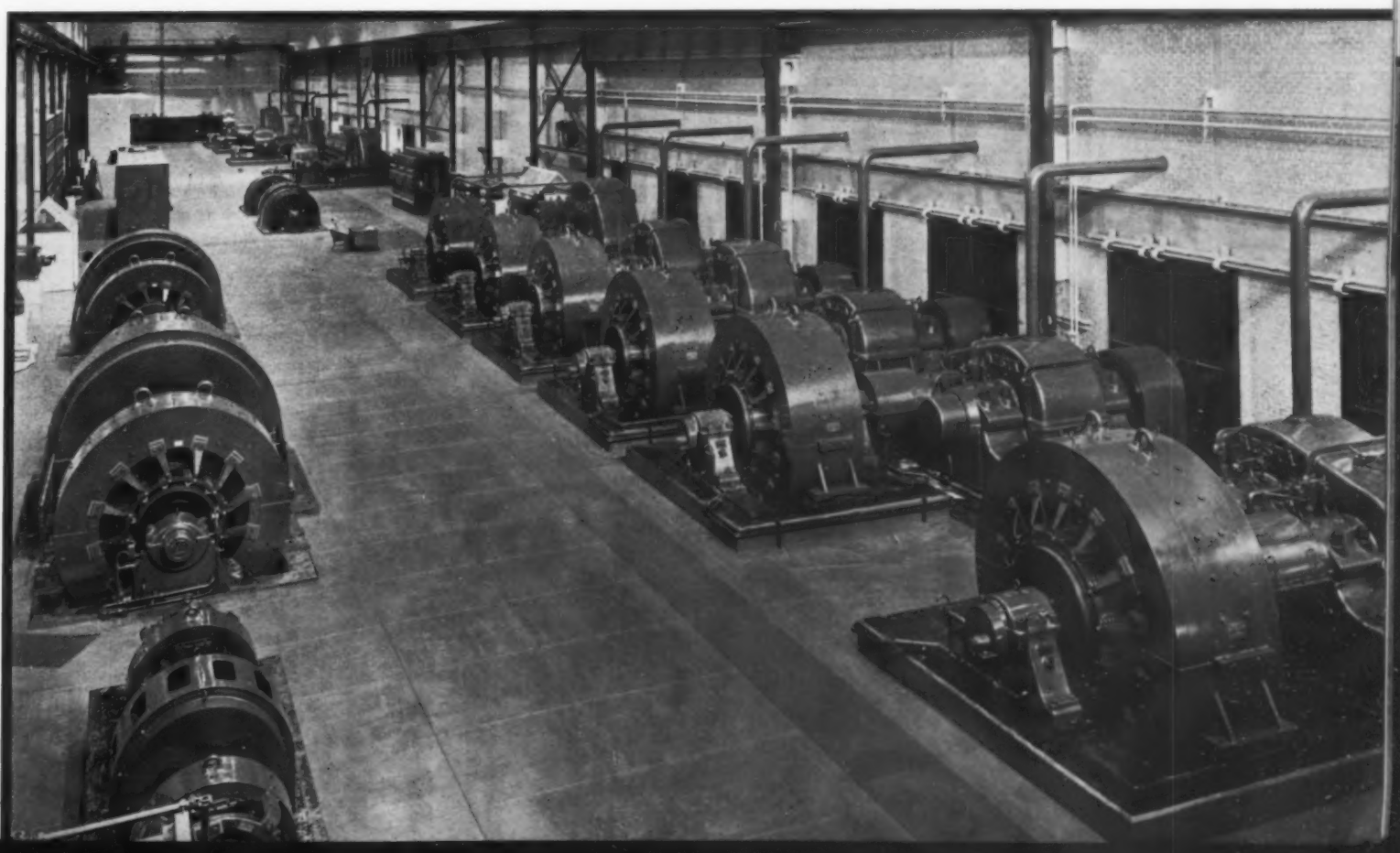
coiler pit, affords a means of transmitting messages between inspectors at the end of the mill and the rollers at the finishing train. Another synchronous tie links the flying shear sequence with the setting on the dial located on the control pulpit. Thrustors have been widely applied to water, air and steam valves.

MOTOR ROOM

Laying between the hot mill building and the slab storage is the motor room, a building 525 ft. long x 65 ft. wide. Here are located all main drive motors of the hot mill stands, with their reduction gear sets. To supply DC. power for the finishing mill motors there are two dual type motor generator sets, each consisting of two 3000 K.W., 600 volt, 5000 amp. DC. generators driven at 360 RPM. by one 8600 HP., 6600 volt, 3 phase, 60 cycle, 90% P.F. synchronous motor, Excitation for these sets is furnished by one 250 KW., 250 volt D.C. generator driven by a 400 HP., 440 volt, 1200 RPM. squirrel cage motor, with a 50 K.W., 250 volt shunt pilot exciter on the same shaft.

Twelve 6000 ampere breakers serve to connect the six finishing mill drives to the above generators. Speed variation is effected by motor-operated rheostats in the generator field circuits. These are controlled by the mill operators, and are supplemented by vernier rheo-

Housed in this 525 foot long x 65 foot wide motor room are all the main drive motors of the hot mill with their reduction gear sets.



stats located on the control benches. Dynamic braking affords emergency stops.

To record performance of the main drives, instruments are installed as follows:

1—Graphic totalizing wattmeter for the two 6600 volt incoming lines.

4—Graphic wattmeters for the 3000 HP. roughing mill motors.

1—Graphic totalizing wattmeter to record the combined input to the two 6000 KW. motor generator sets.

7—Graphic D.C. ammeters for the 600 volt D.C. finishing mill motors.

All graphic instruments are equipped with a chronograph pen. There is also a watthour meter for each roughing mill motor, and for each motor generator drive. The usual indicating instruments are installed on the control desks in the mill pulpits. A special set of indicating instruments was also installed to make possible a detailed study of the finishing train drives.

D.C. auxiliary power is supplied by two 1500 KW., 250 volt D.C. self excited motor generator sets, each driven by a 2145 HP., 6600 volt, 720 RPM., 80% P.F. synchronous motor.

Motor cooling is accomplished by a recirculating system, which also ventilates the motor room. Air is drawn into the machines from the motor room and recirculated through the fin-type water coolers. Fans in connection with this system are as follows:

1—2500 c.f.m. fan for edging mill motors. Driven by a 5 HP., 440 volt squirrel cage motor.

1—15000 c.f.m. fan for No. 1 rougher. Driven by a 10 HP., 440 volt squirrel cage motor.

2—20000 c.f.m. fans for auxiliary M.G. sets, each driven by a 15 HP., 440 volt squirrel cage motor.

2—60000 c.f.m. fans for finishing train motors, each driven by a 50 HP., 440 volt squirrel cage motor.

2—60000 c.f.m. fans for the two finishing train M.G. sets, each driven by a 50 HP., 440 volt squirrel cage motor.

1—40000 c.f.m. fan for make-up air in the motor room, driven by a 15 HP., 440 volt squirrel cage motor.

Air filters are of the oil-immersed travelling screen type. There are two units in the make-up ventilating system, rated at 35,000 c.f.m.

For coilers, mill runout table and piler approach table, there are five variable frequency motor generator sets located in a separate motor-generator building lying along the west side of the runout table. The sets are of the dual motor type, rated at 166/500 Kva., 147/440 volts, 3 phase, 20/60 cycles, and driven by two 125/250 HP., 300 volt DC., 400/1200 RPM. motors connected in series across the 600 volt DC. finishing mill system. Excitation for these sets comes from a 100 KW., 250 volt DC. exciter generator driven by a 150 HP., 440 volt, 1170 RPM. squirrel cage motor. This room also has a ventilating system with 60,000 c.f.m. fan, air filter and air cooler.

Two banks of auxiliary transformers, each made up

Basement of 56" continuous strip mill motor room. Quite a portion of the necessary electrical control equipment is located in this room.

of three single phase 667 Kva., 6900/460 volts transformers, supply 440 volt power for all mill auxiliaries, lights, etc.

Rotary electrical machinery in the strip mill plant total as follows:

	Number	Total HP.
Motors—Hot Mill proper	476	39,735
Generators	27	26,735
Total Hot Mill proper	503	66,470
Motors—Finishing and processing	125	3,220
Generators	10	320
Total Finishing and processing	135	3,540
Motors—Auxiliaries and cranes	400	8,900
Grand Total	1038	78,910

A summary of the 6600 volt connected load of the strip mill and its processing department is as given below:

	K.V.A.
No. 1 Roughing Stand	2,500
No. 2, No. 3 and No. 4 Roughers	7,460
Finishing Train M.G. Sets	14,250
Auxiliary M.G. Sets	3,560
Spray Pumps	1,660
Auxiliary Transformers 2 x 2000 KVA	4,000
Skin Pass M.G. Set	664
Flying Shear M.G. Set	621
Total 6600 Volt Load	34,715 KVA.

Located at the end of the motor room is a roll shop containing one 60″ x 24 ft. roll grinder, and one 24″ x 16 ft. grinder. Two 2300 c.f.m. air compressors for general air supply throughout the mill are also placed here.

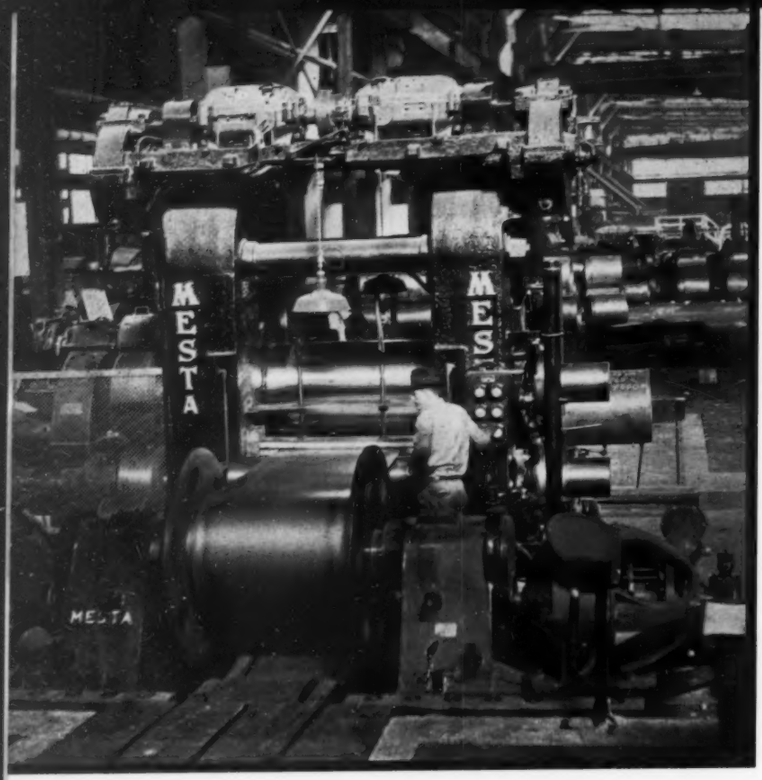
Among the various units located in this strip finishing and processing department is this coil cut-up line as shown to the right.

Herewith is a general view of the strip finishing and processing department. This is an extension out from the end of the hot mill.

PROCESSING DEPARTMENT

Extending on from the end of the hot mill are the strip finishing and processing departments. Two continuous trimming lines, containing leveller, flying shear and piler, with necessary conveyors, serve to bring product, up to 50″ wide x ¼″ thick, to desired sizes. Here are located three single stand two-high skin pass cold mills, which are used for finishing hot rolled product, also two 55″ precision stands and a conventional 66″ mill. There is also a coil cut-up line, a continuous shear, a 192″ x 3/16″ resquaring shear, a 156″ x 3/16″ shear, and two 156″ x 5/16″ shears. A four-arm vertical plunger type pickler, together with a scrubbing and oiling line, furnish cleaning facilities.

Box annealing facilities at this point are composed of four radiant tube type annealing covers, with twelve bases. The furnaces will accommodate sheets up to 84″ x 186″, or coils up to 44″ diameter x 50″ high. A normal cycle calls for heating at a rate of approximately 1½″ total sheet width per hour to a temperature of 1380 degrees F., and holding 16–18 hours. The total heating and holding cycle rate is about one hour per inch of total sheet width. Gas of 500 Btu. per cu. ft.



To the left is shown one of three single stand two-high skin pass mills located in the strip finishing and processing department.

is used as fuel. Four 4000 cu. ft. per hr. gas machines supply means for controlled atmosphere in these furnaces.

This department also houses a continuous roller hearth normalizing furnace, 150 ft. long x 96″ inside width. About one-half of the hearth rollers are water cooled, and the balance are dry shafts. The furnace has a capacity of about 130 tons per day, with a cycle of about 15 minutes in the furnace, and 500 Btu. mixed gas is the fuel. The furnace has three zones of full-floating air-gas ratio control.

The layout of this strip plant differs somewhat from the usual plan in that the hot mill and hot finishing departments only are grouped together, while pickling, cold rolling, etc., are located in buildings attached to the previously installed tinplate plant.

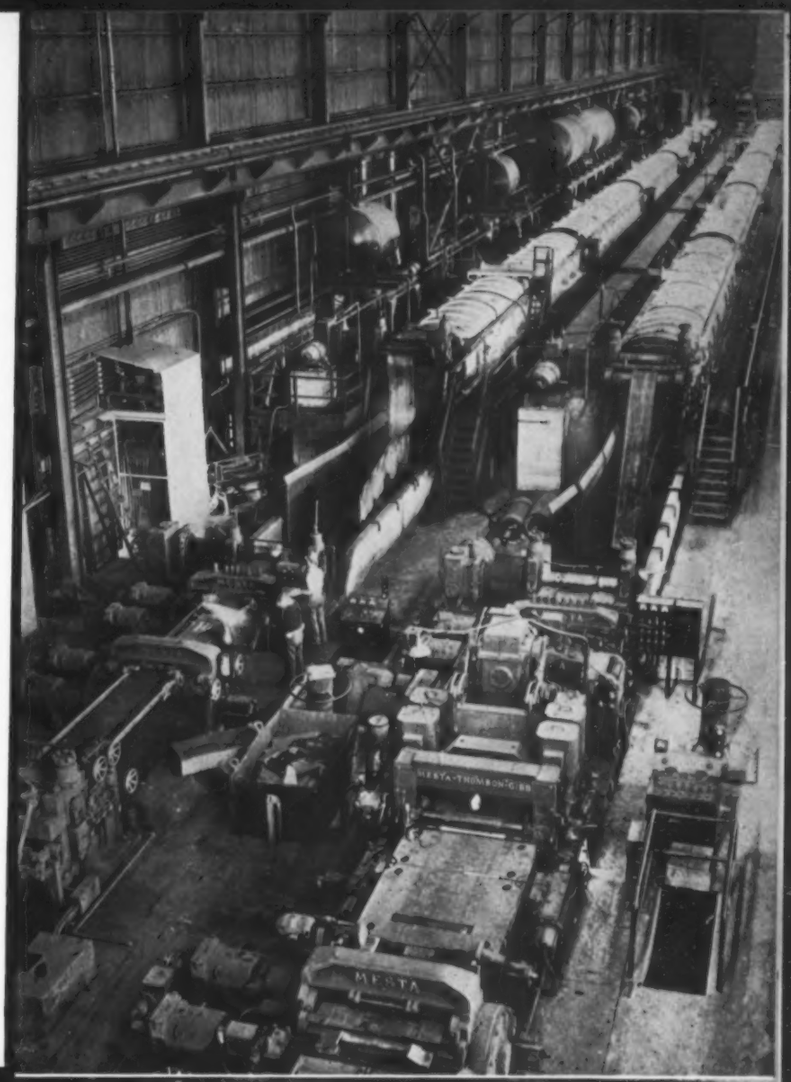
LUBRICATION

Hot mill pinions and pinion bearings are lubricated by an automatic oil system of 10,000 gal. storage capacity, and 450 GPM circulating capacity. A second set of the same size lubricates the reduction gears, reduction gear bearings and edgers. An oil of 1750 sec. Saybolt viscosity at 100 degrees F. is used in both of these systems. A 20,000 gal. system, with a 300 G.P.M. circulation, serves the oil-flooded bearings on the back-up rolls with an oil of 2300 sec. Saybolt viscosity at 100 degrees F. Main motor and motor generator bearings are supplied with a 320 viscosity oil by a circulation of 50 G.P.M. from a 1500 gallon system, while the vertical edging stand is oiled with 600 viscosity oil from a 1000 gallon system with a 5 G.P.M. circulation. All of these systems are completely automatic and are equipped with oil coolers, pumps and centrifuge.

Pressure grease systems lubricate the roller bearings on the work rolls, an individual automatic pump being used for each stand. Hand operated pressure grease systems are provided for mill tables, coilers and other auxiliary equipment.

Also located in the hot strip finishing and processing department as shown below is this leveller with rotary cutting shears.

At the right is shown the two parallel continuous picklers. The speed of strip through these continuous picklers ranges from 70 to 250 feet per minute.



COLD STRIP MILL

Interconnected with the new strip development is a complete cold reduction installation with a capacity of about 25,000 gross tons per month. Hot rolled strip steel of 13–16 gauge is rolled down to tinplate ranging .03″–.007″ in gauge.

CONTINUOUS PICKLERS

Hot rolled strip proceeds first to the continuous picklers, of which there are two lines. Each line is made up of four acid tanks, one cold water tank and one hot water tank. The former tanks are 60′ in length x 5′ in width x 4′–2″ in depth, with 7500 gallons capacity. The water tanks are 23′–6″ x 5′–0″ x 4′–2″ in size, with 2900 gallons capacity. Tanks are constructed of ⅜″ steel plate, properly stiffened, and lined with ¼″ rubber protected by an 8½″ lining of acid proof brick

Below is illustrated the two 5 stand tandem cold mills for rolling tin plate gauges. One mill has a monthly capacity of 11,000 gross tons while the other mill has an average of 14,000 gross tons per month.

laid in acid resisting cement. Tank covers are of 3/16" arched steel plate, also rubber lined, and vented through scrubbers, with fumes finally expelled by exhaust fans through an outside stack equipped with an exhaust head. Pickling solutions, of a strength of 9–11% sulphuric acid, are held at 180–200 deg. F. by automatic temperature controllers. Speed of strip through the picklers ranges 70–250 ft. per minute. The overall length of the picklers is approximately 500 ft. and includes, besides the tank line, the usual uncoiler, leveller or processor, stitcher, looping pit, pinch rolls, scrubber, shear and recoiler. One line is equipped with an electric welder and flash trimmer as well as a stitcher.

There are twelve manually operated pressure grease systems, supplying 433 bearings, on the pickling lines.

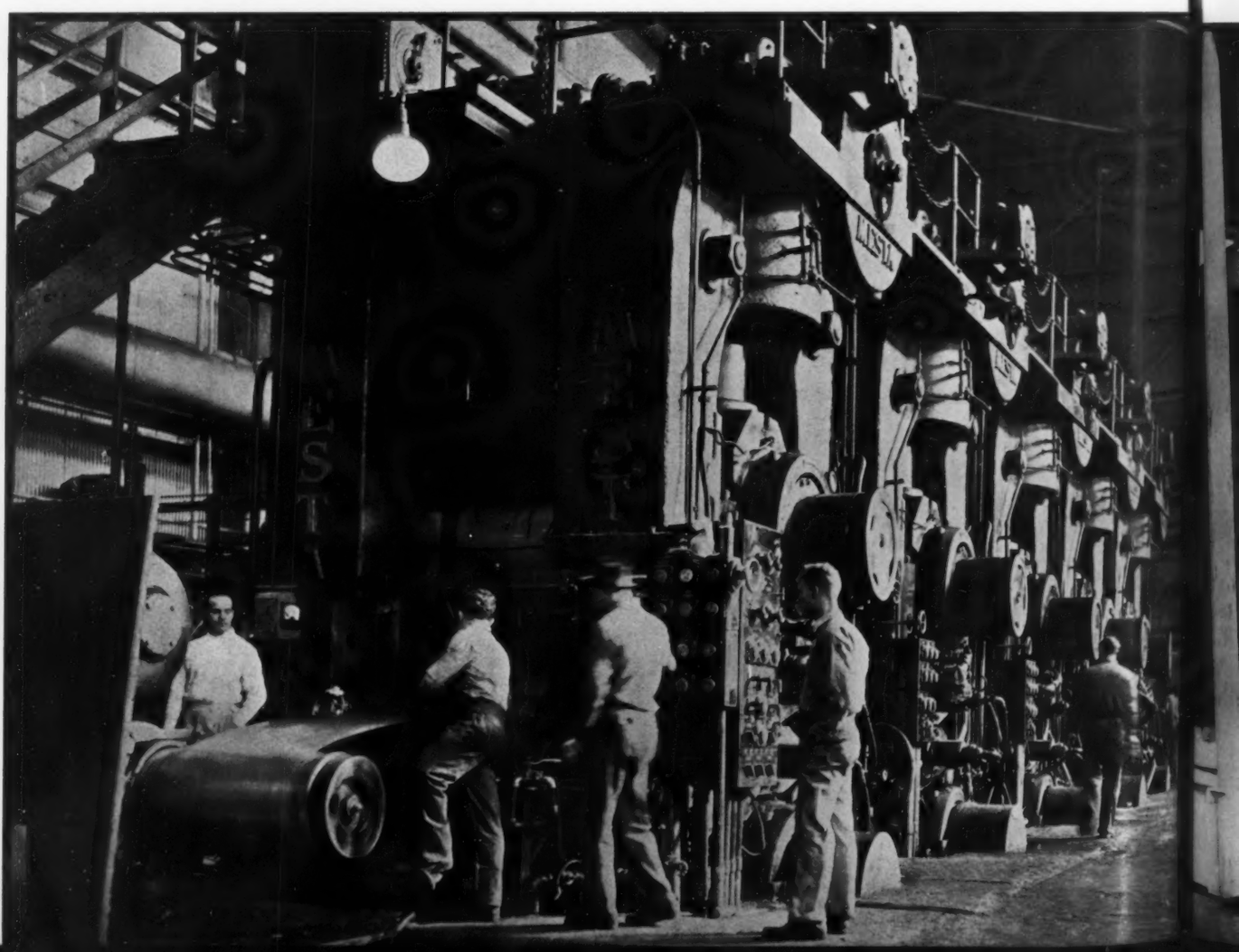
There are two 15 ton cranes installed in this building.

COLD MILLS

The cold mill building, which is conveniently located with respect to the pickling building, houses two 42" tandem mill trains, each consisting of five 4-high stands. One train employs an 800 H.P., 600/1000 R.P.M., 600 volt DC. shunt motor on each stand, while the other has a 500 H.P. motor on the first stand, a 1000 H.P. motor on each of the next three stands, and a 1250 H.P., 600 volt DC. compound motor on the last stand, all of 600-800 R.P.M. Roller Bearings are used on all work rolls with sleeve bearings on the back-up rolls. Stands are spaced on 13 ft. centers. Speeds of these mills are as follows:

	Motor RPM.	Roll RPM.	Strip Speed Ft. per Min.
No. 1 Mill			
No. 1 Stand	600/1000	28.9/48.3	138.4/231.0
No. 2 Stand	600/1000	57.4/95.7	274.5/457.4
No. 3 Stand	600/1000	94.4/157.3	451.0/751.6
No. 4 Stand	600/1000	135.7/226.2	648.4/1081.0
No. 5 Stand	600/1000	144.6/240.9	691.0/1151.3
No. 2 Mill			
No. 1 Stand	600/800	54.5/72.7	260.6/347.5
No. 2 Stand	600/800	86.6/115.5	414.1/552.1
No. 3 Stand	600/800	144.5/192.7	690.8/921.0
No. 4 Stand	600/800	205.1/273.5	980.1/1306.8
No. 5 Stand	600/800	241.0/321.4	1151.8/1535.7

Close-up view of one of the 5 stand tandem cold mills. Accuracy of gauge of product is insured by the installation of electro-limit gauging equipment.



Power for No. 2 mill is furnished from a 3500 KW., 600 volt DC. generator which is one unit on the shaft of a large frequency changer, which is located in the cold mill motor room, and which will be subsequently discussed. Power for No. 1 mill is supplied by a four-unit 3500 KW. motor generator set consisting of two 1250 KW., 600 volt DC. generators for the mill, one 1000 KW., 250 volt DC. generator for auxiliary DC. power, all driven by a 4800 KVA., 6600 volt, 25 cycle, 750 RPM. motor. This set is separately excited by a 60 KW. exciter. The recoiling reel is driven by a 150/225 HP., 225/450/900 RPM., 600 Volt DC. motor.

One tandem train has a monthly capacity of about 11,000 gross tons of strip, and the other, of later design, 14,000 tons. Accuracy of gauge of this product is ensured by electro-limit gauging equipment on these mills.

Each tandem mill is provided with an automatic oiling system of 4200 gal. storage and 120 GPM. circulating capacity for the gear drives, and two more, slightly larger, for the mill bearings. Oil of 1700 sec. viscosity at 100 deg., is used in the former, and 2300 sec. viscosity at 100 deg., in the latter. All oil passes through pressure filters before use on the bearings and gears and is centrifuged when necessary. There is also an automatic pressure grease system for work rolls and other bearings on each mill.

Two roll grinders located in this department serve to keep the mill rolls in proper condition. One 60 ton crane and one 25 ton crane are installed in this department.

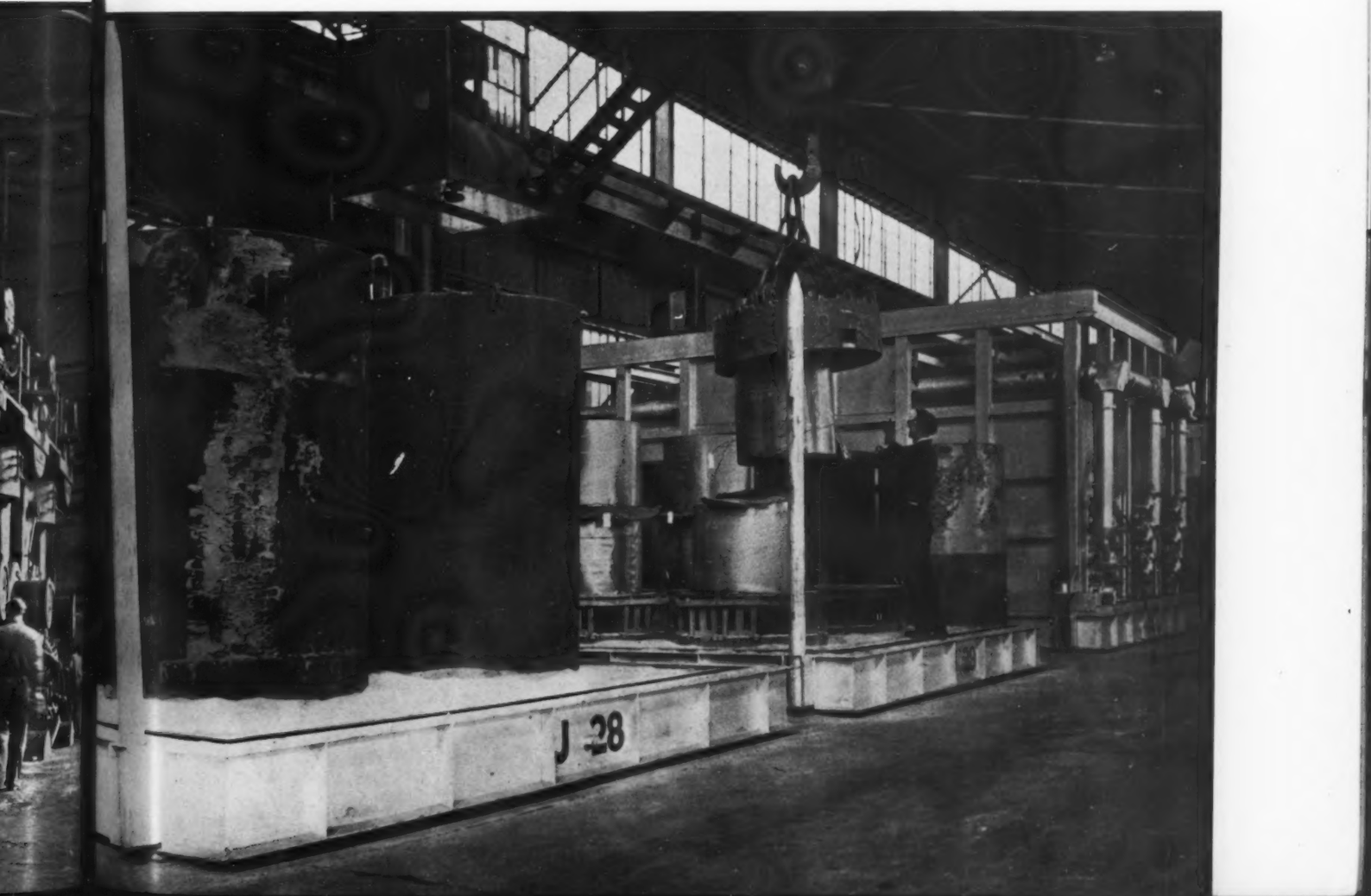
ANNEALING

The annealing section of the cold mills consists of sixteen radiant tube type annealing covers, with forty-eight bases located in two parallel buildings. The covers are 12′–0″ x 22′–0″ x 7′–4½″ inside dimensions. The heating elements are arranged along the two sidewalls and through the center of the cover. Each element is equipped with a combination premix and diffusion type of burner, so that each tube can be adjusted independently. The furnace is usually charged in eight stacks. Usual annealing temperature is about 1300 degrees F. and a typical cycle is made up of 26 hours coming up to temperature, 10 hours soaking time, and 45 hours cooling time.

Two 25 ton cranes serve to charge and move the annealing covers.

Three gas atmosphere machines, each of 15,000 cu. ft. per hour capacity, provide the proper furnace atmosphere.

In the lower illustration may be seen a portion of the annealing section in the cold mills which consists of sixteen radiant tube type annealing covers, with forty-eight bases.



To remove the palm oil from the strip after cold rolling, five electrolytic cleaning lines, designed for a maximum strip width of 42″, have been installed.

ELECTROLYTIC CLEANING

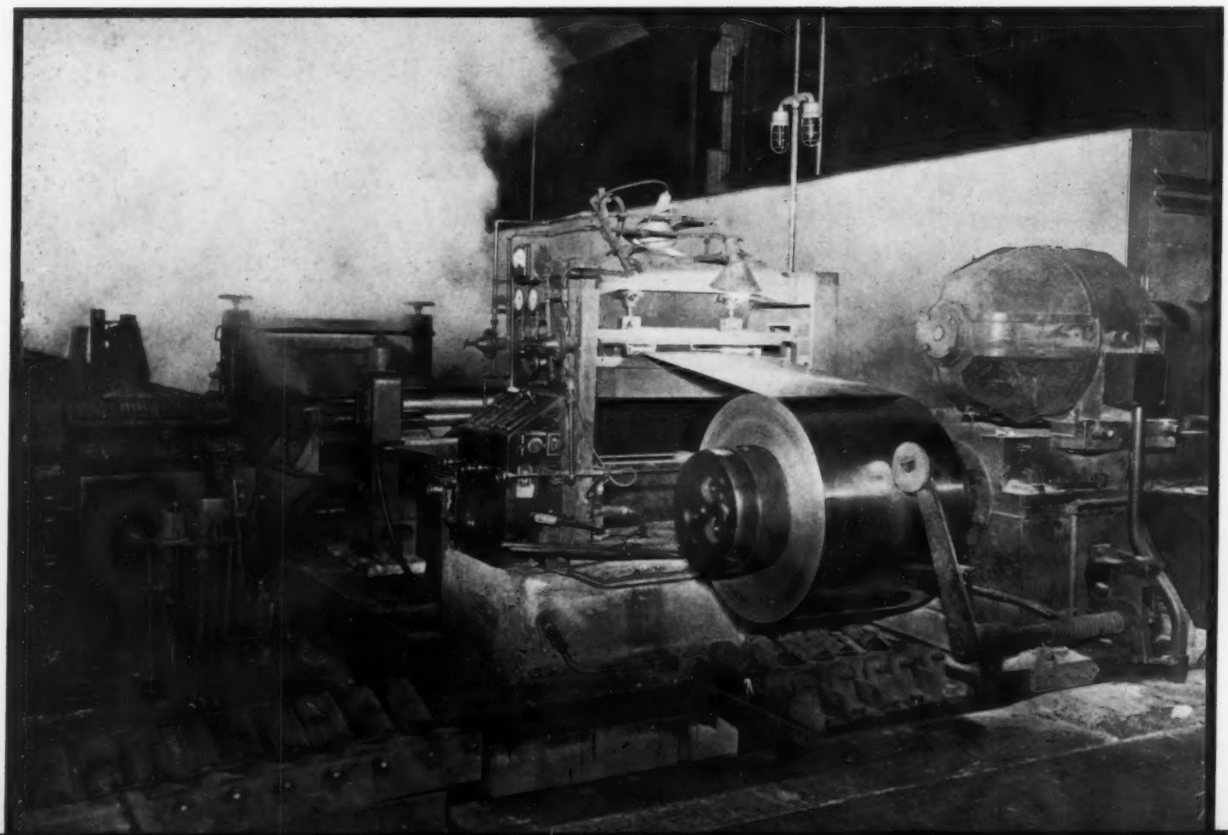
Five electrolytic cleaning lines, designed for a maximum strip width of 42″, serve to remove palm oil from the strip after cold rolling. Coils are brought to the cleaning lines by ram-type 12,000 lb. tractors, and placed on a feed reel. A strip welder serves to tie the coils into a continuous feed, which passes first through a washer 10 ft. long x 5′–5″ wide at speeds ranging 300-1000 ft. per min., and on to an electrolytic cleaning tank 63′–0″ long x 5′–0″ wide x 2′–6″ deep. The electrolytic solution, which contains a cleaning solvent at concentrations of 1–1¼ oz. per gallon of solution, is automatically controlled at about 190 degrees F.

The strip next passes through a scrubbing unit and on to a water rinse tank 22′ x 5′ x 2′–6″, automatically held at 200-210 degrees F., and followed by an air jet dryer.

All tanks in these units are constructed of steel plate, electrically welded throughout, and reinforced with angles and channels.

Nineteen manually operated pressure grease systems service 635 bearings on the cleaning lines.

Winding reel at the delivery end of electrolytic cleaning line. This reel is driven by a 40/50 h.p., 400/1600 rpm., 230 volt motor.



SKIN PASS MILLS

For skin passing the cold rolled strip, two 42″ two stand 4-high mills are provided. The rolls of these mills run at 250-375 RPM., giving a surface or strip speed of 1194–1791 ft. per min. Each mill has a capacity of about 8000 tons per month.

There are also two 42″ single stand 4-high mills each having a monthly capacity of about 6300 gross tons. Strip travels through them at a speed of 790 feet per minute.

All of the skin pass mills are equipped with roller bearings on the work rolls and sleeve bearings on the back-up rolls. Lubrication for the gear sets and mill bearings is provided from fully automatic oil pressure systems, while automatic pressure grease systems supply the anti-friction bearings.

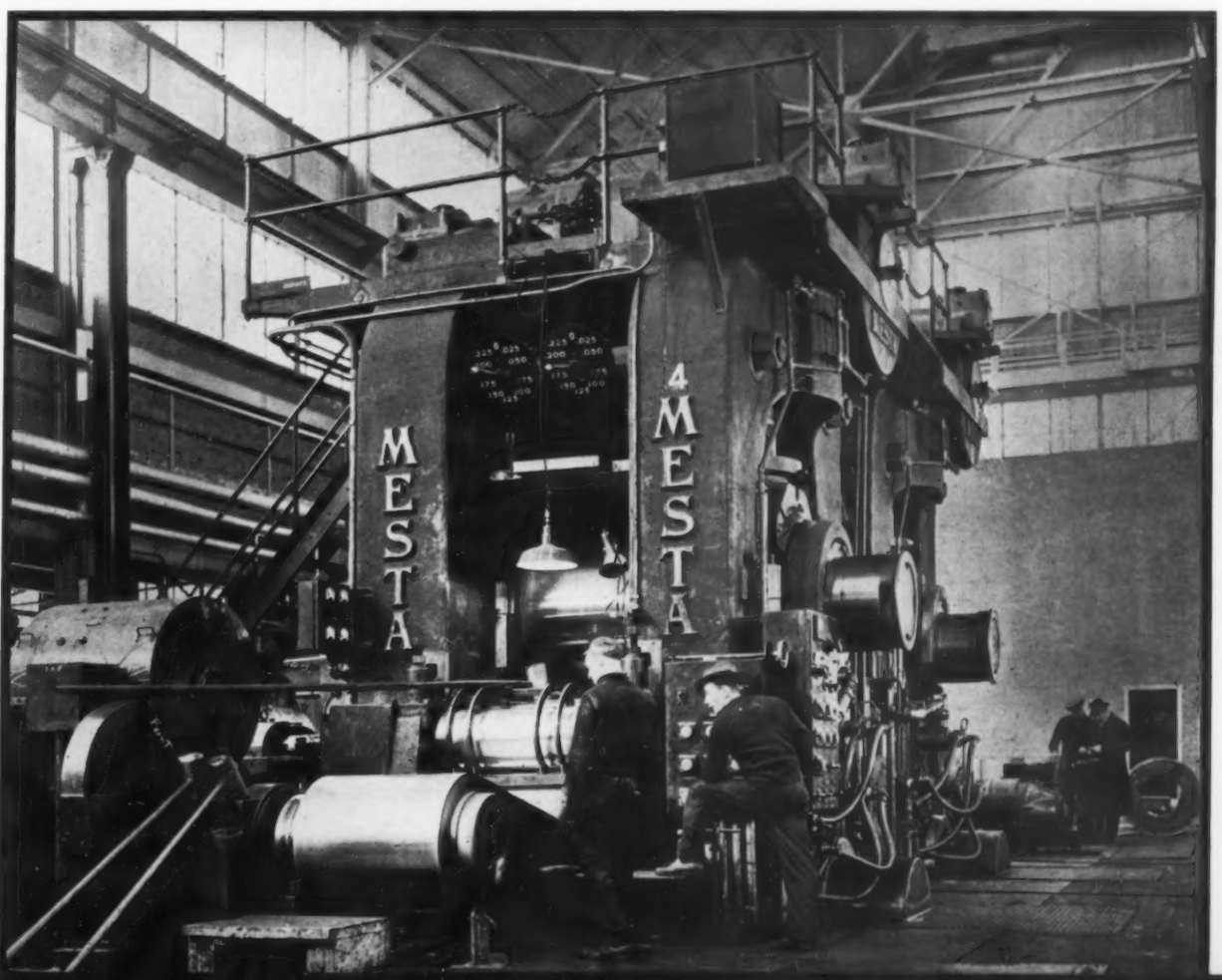
Skin pass mills are all located in a separate building served by a 60 ton and a 25 ton crane, and also houses seven trimming lines designed to level and shear 22-38 gauge in widths up to 42″ into lengths of 18″–40″. Each line has a capacity of approximately 5 tons per hour, and material speed through the lines ranges 400-620 feet per minute. The trimming and shearing motors operate from a separate motor generator by Ward-Leonard Control.

Rotating machinery for cold reduction, including cold mills, skin pass mills, finishing, etc., totals as follows:

	Number	Total H.P.
Motors	951	11,986
Generators	57	13,800
Total	1008	25,786

Completion of the tinplate process is accomplished in the white pickling, tinning and assorting departments. A four-arm vertical plunger type pickler, with a capacity of about 26 tons per hour, prepares the plate for subsequent tinning, which is performed in ten 75″ three-way machines and eight 64″ two-way machines. The former have a capacity of 240 base boxes per eight hour turn, and the latter 200 base boxes. Tin pots are heated with 500 Btu. per cu. ft. gas, fired through an immersion type burner. There are three duplex tinplate weighing and assorting machines for all gauges of tinplate in sizes from 18″ x 18″ to 40″ x 40″, including automatic feeders, conveyers and pilers. Each machine has a maximum capacity of 3500–3600 plates per hour.

For skin pass rolling there are installed, two 42″ two stand 4-high mills. Shown below is a view of one of these mills. Each mill has a capacity of about 8000 tons per month.



CONVENTIONAL SHEET AND TIN PLATE MILLS

In addition to the recently installed expansion just discussed, there is a large tinplate plant of the older, conventional type, with a capacity of approximately 4,500,000 base boxes annually. This mill is made up of forty-eight conventional 2-high hot mills grouped six to each motor drive. Each mill has a 500 Btu. gas fired furnace for pairs, packs and run-overs, as well as a shear and mechanical doubler. Black pickling equipment includes three four-arm vertical plunger picklers.

Below is shown the tin sorting department where the product is given its final inspection before delivery to the customer.

After being inspected and approved the product is moved into this warehouse as shown to the left. Here it is packed and made ready for final shipment.

Heat treating equipment consists of one normalizer fired with gas of 500 Btu. per cubic ft., two black annealing tunnel kilns, 325 ft. in length, also gas fired, and fourteen white annealing furnaces, built in pairs and side-fired with fuel oil. There are fifteen tandem trains of cold rolls, each consisting of three 2-high stands. Two white picklers and thirty-six tinning machines complete the process.

The sheet mill includes two 3-high mechanical roughing mills, each equipped with a two-lane continuous furnace with walking beam type conveyor; eleven two-high conventional roughing mills; and eight 2-high finishing mills, with continuous oil-fired pack furnaces, doublers and finishing shears. Cold rolling facilities are supplied by six single 2-high mill stands. Thirty-box annealing furnaces built in pairs and side-fired with oil, afford adequate heat treating capacity. There are eight galvanizing pots, six of 48″ and two of 60″ size, together with the necessary pickling, finishing and corrugating equipment. A wide range of steel sheets of the conventional black, blued and galvanized types, in standard gauges and in widths up to 48″, are turned out in large quantities, as well as roofing products, corrosion-resisting material, etc.

Two complete jobbing-mill units are also located in the sheet mill. Each unit consists of an oil-fired bar-heating furnace, a roughing mill, a finishing mill and a continuous oil-fired open annealer, as well as roller leveller and shear. Plates in gauges from No. 3 to No. 16, and up to 60″ in width, are produced.

SHIPBUILDING

Because of the location of the Maryland Plant at tide-water, adjacent to the port of Baltimore, it is natural that shipbuilding activities were developed here. There are ship building ways, of lengths ranging from 348 to 600 ft., equipped with modern cranes and other necessary handling facilities, together with complete shops.

Shipbuilding activities at this Maryland plant are very prominent. This view shows the shipbuilding ways of lengths ranging from 348 to 600 ft.

POWER AND OTHER SERVICES

The recent installations of steel producing units described in the foregoing necessitated a concurrent expansion in power supply for the plant. Previously the power supply of the plant was derived from the following sources:

Six 4000 KW., 6600 volt, 25 cycle generators driven by four cylinder twin-tandem gas engines, cylinders 47″ bore x 60″ stroke. Blast furnace gas is the fuel. There is a 239 HP. waste heat boiler installed in the exhaust line from one engine.

One 20,000 KW., 6600 volt, 25 cycle generator, driven by a 12-stage, 1500 RPM., 36,800 HP. Curtis steam turbine, with a 33,000 sq. ft. surface condenser.

One 10,000 KW., 6600 volt, 25 cycle generator, driven by a 10-stage, 1500 RPM., 13,400 HP. Curtis steam turbine, with a 13,600 sq. ft. surface condenser.

Five 7500 KVA., 26,000/6600 volt, 25 cycle, transformers, on a purchased power connection with the local power company.

The power system then totaled a generating capacity of 54,000 KW., plus a purchased capacity of 37,500 KW., totaling 91,500 KW., all on 25 cycles. The new mills then under consideration involved additional demands as follows:

	Hourly Demand	Peak Demand
56″ Hot Strip Mill	15,000	25,000
No. 2 Cold Strip Mill	4,000	5,000
No. 2—10″ Rod Mill	5,000	6,000

As the power company desired to decrease their 25 cycle load rather than extend it, the plan adopted consisted of purchased 60-cycle service, with a 20,000 KW. frequency changer operating between the two systems. This plan permits the 25-cycle system to be fed in part from the power company's 60-cycle system. At the same time, the new mill installations were put in for 60-cycle service.

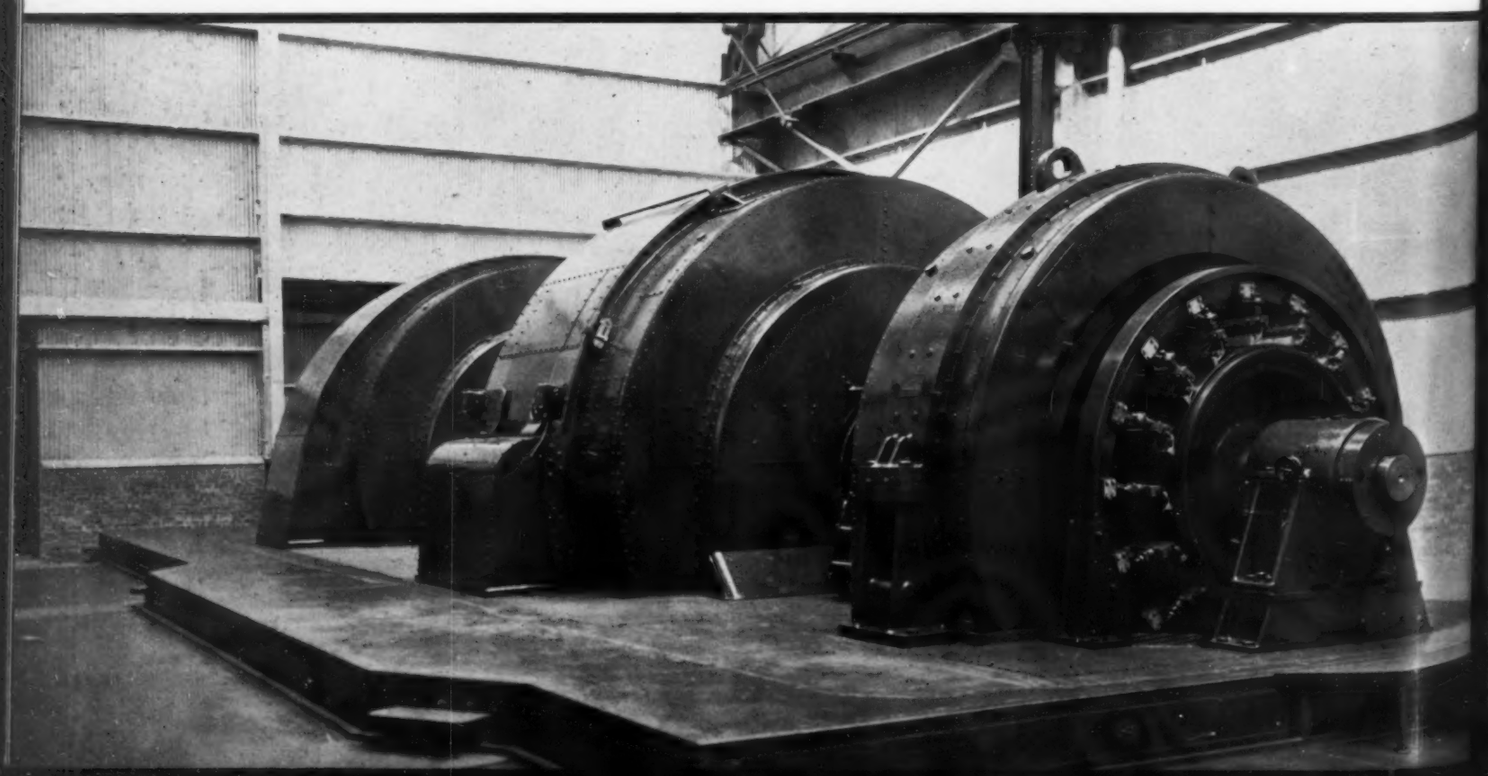
The new 60-cycle service is supplied through two 33 KV., 25,000 KW. circuits from Riverside Station, terminating in the Maryland plant in two 33,000/6600 volt substations. One substation, located about 2000 ft. from the Hot Strip Mill, contains four 10,000 KVA., 3-phase transformers, while the other station, located at the rod mills, has a single 10,000 KVA., 3-phase transformer.

The 20,000 KW. frequency changer is located in the cold strip motor room, as previously mentioned. This substation is over a mile from the plant 25-cycle generating station. The location is advantageous from the stand point of power distribution, as the adjacent Tin and Sheet Mills present a 25 cycle load of about 20,000 KW.

This unit consists of a 25,000 KVA., 6600 volt, 25 cycle, 3-phase, .8 P.F., alternator; a 3500 KW., 600 volt DC. generator supplying power to No. 2 Tandem Cold Mill; a 200 KW., 250 volt DC. exciter for the 28,150 KVA. drive motor; a 200 KW., 250 volt DC. exciter for the 25,000 KVA. alternator; and a 75 KW., 250 volt DC. exciter for the 3,500 KW. generator, all driven at 300 RPM. by a 28,150 KVA., 6600 volt, 60 cycle, 3-phase, .88 P.F. motor.

A unique feature of this unit is the incorporation with it of the 3500 KW. generator supplying power to No. 2 Tandem cold mill, which resulted in a substantial saving in investment cost, and at the same time, allows the frequency changer to be started by Ward-Leonard

Below is shown a view of the 20,000 KW. frequency changer which is located in the cold strip mill motor room. This equipment was necessary in order to take care of the additional power requirements occasioned by the erection of the new strip and rod mill.



control from the adjacent 3500 KW. motor generator on No. 1 Tandem Cold Mill, using the 3500 KW. generator on the frequency changer set as a motor, thus greatly simplifying a normally tedious starting job. This set is designed with special windings in both the 25 cycle and 60 cycle machines, so that the unit can be operated from the 25 cycle end if necessary.

Approximately half of the total power consumption of the plant is generated in the plant, the other half being purchased. With the new mills operating, a total load of 1,800,000 KWH. per day, on a maximum demand of 120,000 KW., is expected, although so far it has not exceeded 1,500,000 KWH. per day on a maximum demand of 102,000 KW. Connected motor load in the entire plant totals about 538,000 HP.

Water rates of the turbo-generators average about 13.2 lb. of steam per KWH. generated.

Steam for power generation, blast furnace turbo-blowers, general processing and plant use is furnished by several boiler houses located at various points around the plant.

Water for the plant originates from two sources. Approximately 100,000,000 gallons per day of salt water, with a salt content of about 1/5 that of sea water, are used, in addition to about 12,000,000 gallons per day of fresh water from artesian wells. Of the latter, about 2,750,000 gallons per day are treated for drinking water and for boiler feed. The former treatment consists of aeration, followed by lime and iron sulphate, settling, chlorination and filtration. For boiler feed purposes, this water is further treated, using sodium sulphide, caustic soda, and sodium phosphate, and in some cases, tannin.

Service shops are located at convenient points throughout the plant, and include brass and iron foundries, electrical repair shop, carpenter, paint, boiler, pattern, sheet-metal and copper, pipe, machine, blacksmith, structural, and locomotive repair shops. The foundries turn out castings for outside sale as well as for the steel plant.

The Maryland Plant is served by Patapsco & Back Rivers Railroad. This terminal switching line with 48 miles of track and 36 locomotives (12 of which are Diesel-electric units) connects the industries on its line, including the Maryland Plant of Bethlehem Steel Company, with the Pennsylvania, Baltimore & Ohio, and Western Maryland Railroads.

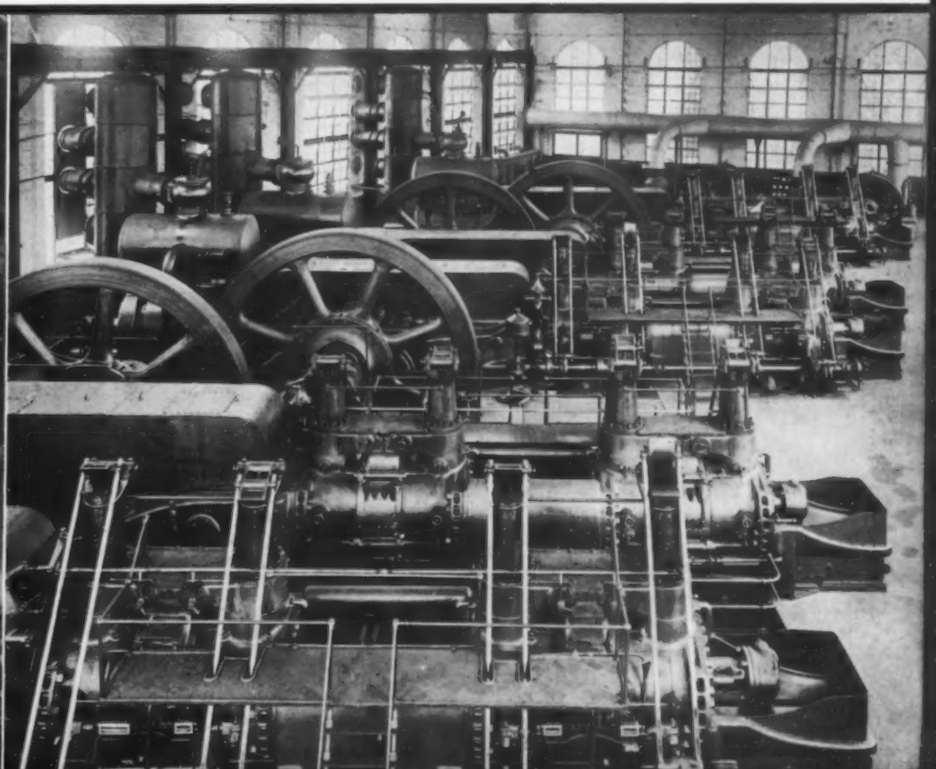
The plant has for its internal operations 9 narrow gauge steam locomotives, 22 standard gauge locomotive cranes, and 969 cars of various types.

For ocean-going vessels there is a 700 ft. shipping pier, with a 35 ft. depth of water at mean low tide, adjoining the ore dock. In addition, barges connect the plant with nearby parts.

Three modern laboratories give adequate facilities for a complete check of the plant processes, ensuring a constant high quality of product. One chemical laboratory serves the coke and by-products departments, and a second serves blast furnaces, open hearth and Bessemer departments. The third is a physical laboratory for the processing divisions.

Below is shown a view of one of the artesian wells which equipment supplies a total of 12,000,000 gallons of fresh water per day. This supply of fresh water plus 100,000,000 gallons of salt water is the average demand per day.

A portion of the power supply for the plant is furnished by six 4000 KW., 6660 volt, 25 cycle generators which are driven as shown below by four cylinder twin tandem gas engines.



GENERAL PLAN

Maryland Plant

BETHLEHEM STEEL COMPANY

Sparrows Point, Md.

...TAINING PAGES RE...

STUDY OF POWER REQUIREMENTS OF A 56" HOT STRIP MILL

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Abstract of paper to be presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28-29, 1938.

▲ TWO of the chief engineering and economic problems arising in connection with the installation of a new hot strip mill are the layout of the power system and the selection of the drives. After the general design of the mill has been determined, past experience on previous installations furnishes a reliable guide for determining the ratings of the electric drives. This phase of the engineering has now become largely a matter of working out the details of the electric drives to suit the peculiarities of the mill design. Because of the large amount of power required, very few steel plants can assume the additional load of a new hot strip mill without major additions to the power system. The determination of the best means for supplying the additional power is largely an economic problem. Since each steel plant power system presents problems peculiar to that system, little general information is available to assist in the solution of the economic and engineering problems involved.

At the time the new 56" Hot Strip Mill, No. 2—42" Tandem Cold Strip Mill and 10" Rod Mill were being considered, the Maryland Plant power system had a total installed capacity of 85,500 KW. This consisted of 48,000 KW in 25 cycle generating units and 37,500 Kva in 25 cycle purchased power capacity. Momentary peaks up to 85,000 KW were being carried regularly with no spare capacity available. To provide for the requirements of the new mills it was estimated that it would be necessary either to install a 30,000 KW generator unit or to provide an equivalent increase in purchased power capacity. After a thorough study had been made, it was decided that it was desirable to purchase the additional power required.

The Consolidated Gas, Electric Light and Power Company, who were supplying the 25 cycle power which was then being purchased, did not wish to extend their 25 cycle system but preferred to reduce their existing 25 cycle load. They proposed 60 cycle service which would include a 20,000 KW frequency changer to provide spare capacity for the Maryland Plant 25 cycle system and to make it possible to supply part of the 25 cycle load from their more efficient 60 cycle system. The inherent advantages of 60 cycle service such as lower cost of apparatus, greater availability of equipment and larger range of synchronous speeds available for motor drives made this proposition attractive. Consequently, 60 cycle service was decided on for the new mills in accordance with the recommendations of the power company.

Sixty cycle service is supplied through two 25,000 Kva, 33 Kv circuits which terminate in two 33/6.6 Kv substations. One substation of 40,000 Kva capacity is located midway between the Hot Strip Mill and Frequency Changer Substations. The other substation, of 10,000 Kva capacity, is located at the Rod Mills. An interesting feature of the frequency changer installation was the addition of a 3500 KW., 600 volt DC generator on the end of the set. This generator supplies power to No. 2—42" Tandem Cold Mill. This combination represents an economy in space, foundations, auto-transformers and switching equipment and allows the frequency changer to be started by Ward-Leonard control from the adjacent 3500 KW. motor generator on No. 1 Tandem Cold Mill, using the 3500 KW. generator on the frequency changer set as a motor. Thus a normally tedious starting job is simplified greatly. Both the 25 cycle and 60 cycle machines are provided with amortisseur windings so that in an emergency the set can be brought up to speed by connecting the 25 cycle end to a generator in the power house and bringing the set and the generator up together.

Since the 56" Strip Mill has operated for only a few months at low capacity, overall energy consumption figures are not representative of practice under normal conditions. A typical day's run on .090" and .075" strip gave an overall energy consumption of 82 KWH per gross ton charged. This figure includes power for mill auxiliaries and water and steam systems. The maximum instantaneous demand observed to date is 28,000 KW and the overall power factor under load usually varies from 97% lag to 97% lead. These figures are considered representative of the performance of the mill when operating at normal capacity.

The 56" mill consists of a vertical edger which serves as a roughing scale breaker, four 56" roughing stands, a finishing scale breaker and six 56" finishing stands. Each roll of the vertical edger is driven by an individual 300 HP., 500 RPM., 440 volt squirrel cage motor. One motor is located in the motor room and one in a pit under the mill floor. This arrangement simplifies the mechanical design of the edger and the operation is quite satisfactory. Load division between motors is never perfect, but the motors are of ample capacity and the method of drive is satisfactory from the standpoint of mill operation.

A study of the load conditions proposed for the mill indicated that synchronous motors would be satisfactory for the roughing train provided the roll speeds were selected so as to keep the peak loads within reasonable limits. Synchronous motors were desirable because of simplicity of control and lower overall cost as compared with other forms of drive. The four roughing stands were geared for surface speeds of

181, 285, 430 and 430 feet per minute respectively. Each stand is driven by a 3000 HP, 100% power factor synchronous motor with 300% sustained pull-out torque.

The six finishing stands are each driven by a 3000 HP 600 volt DC motor with 2/1 speed range. No. 2 scale breaker is driven by a 500 HP., 600 volt, 150/600 RPM. DC motor. Power is supplied through two 6,000 KW synchronous motor generators. The control arrangement is conventional.

The AC and DC switching equipment for the mill includes 13 graphic instruments for recording the total input to the mill, input to the main motor-generators, input to the four 3,000 HP roughing mill motors and current input to the finishing mill motors. Using these instruments; a special set of indicating instruments and a photographic recorder, a series of tests were made on the main drives. The test results may be summarized as follows:

A. Roughing train loads.

When rolling 4½" thick low carbon slabs to strip ranging from .047 x 38⅜ and .060 x 50⅛ to .106 x 46¼ the range of rolling loads on the roughing train was as follows:

Stand No. 1	2900–3700 HP
Stand No. 2	2300–5100 HP
Stand No. 3	4500–5600 HP
Stand No. 4	3800–6000 HP

Because of the tendency for the steel to slip in the rolls occasionally it was found undesirable to operate any of the motors at any time with reduced excitation. This is especially true of No. 1 Stand in which slippage is most likely to occur. Slippage causes violent changes in load and amplifies the inherent tendency for the rotor of a synchronous motor to oscillate with sudden changes in load. Under such conditions a synchronous motor may fall out of step on relatively light loads if operated with less than full excitation. For this reason 3000 HP is not considered excessive for No. 1 Stand, even though the heating load is well below this figure. It is almost a universal custom to operate synchronous motors with reduced excitation at light load to reduce losses and heating. However, this has been found to be an unsafe practice for strip mill roughing stand drives.

B. Finishing train loads.

When finishing the same sections for which the above roughing mill loads were given, the finishing train loads were as follows:

Stand No. 5	3200–4880 HP
Stand No. 6	2200–4300 HP
Stand No. 7	2100–3900 HP
Stand No. 8	1800–3700 HP
Stand No. 9	1700–4400 HP
Stand No. 10	1500–3700 HP

All motors operated well within the limits of the available 2/1 speed range. Ample margin is available for higher operating speeds and to take care of roll wear.

C. Total mill input.

The base load made up of no load running losses, and the requirements of fans, pumps, cranes and miscellaneous auxiliaries is 5500 to 6500 KW. The maximum peaks with only the roughing train loaded range from 8500 KW to 11000 KW. With only the finishing train loaded the peaks may range from 16,000 KW to 24,000 KW. Occasional peaks of 28,000 KW occur when the finishing mill peak and a roughing stand peak coincide.

D. Energy—elongation curves.

One of the questions which has interested steel mill engineers is the effect of higher mill operating speeds on the energy consumed by the main drives.

In order to shed some light on this interesting question, tests on several schedules were worked out in detail and the results plotted in curves of net energy consumption per net ton rolled against elongation. The curves obtained in this manner indicate that modern high speed mill require appreciably less energy for the main drives per unit of work done, than older slow speed mills.

E. Dynamic braking for finishing stands.

The finishing stand drives are equipped with dynamic braking control for emergency stopping. Dynamic braking is applied in three steps. Oscillograms were made to show the performance of this control feature.

INSTRUMENTATION OF A MODERN HOT AND COLD STRIP MILL

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Abstract of paper to be presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28-29, 1938.

PART I - By J. L. WHITTEN

▲ THE construction of continuous strip mills in America has been so much of a continuous procession that my work in the steel industry has almost been as a strip mill specialist. That this is becoming an international topic is evidenced by the construction abroad of new continuous mills in Russia, Japan, and I had the privilege recently of being in England to work on equipping the first and second continuous wide strip mills in that steel minded country. This experience culminates a long contact with the most interesting instrumentation problem in the steel industry; because, invariably an entire plant was involved and the matter could be approached as a completely planned unit with all individual control applications considered in the light of the requirements and standards of the entire plant.

Starting with the installations of the Lackawanna Plant of Bethlehem Steel and the Gary Sheet and Tin Mill, there have followed the installations of the Ford Mill, the Russian Mill at Zaporojie, the Jones and Laughlin Mill at Pittsburgh, Great Lakes Steel at Detroit, the Republic Mill at Cleveland, Bethlehem at

Sparrows Point, The Richard Thomas Mill, England, the Irvin Mill at Pittsburgh and the proposed improvements at Cuyahoga Works of American Steel and Wire. Although one job has followed on the heels of the other, no two are exactly the same in mill, furnace or instrument design. This is indeed typical of the progress of American industry in which we can justly take so much pride.

For controlling the operation of the slab reheating furnaces it has become quite general practice to apply automatic regulation to the fuel and air to the soaking zone of the furnace. With the idea of treating this zone as a soaking pit, the temperature is measured by an radiation tube or thermocouple placed to take the temperature on the inside face of the roof. This temperature impulse, transferred to a recording controlling potentiometer, of either electric or air operated type regulates the fuel input to the furnace in accordance with the demands of load variation, full furnace hold-overs or shut down periods. It is particularly important to recognize the *load* variation in this type of furnace and the controlling system should embody load compensation. Fuel-air rationing equipment, of course, will regulate the air supply. While the uniformity of slab heating can be best accomplished by automatic temperature control of the soaking zone, it is not usually thought necessary to control the temperature of the heating zones of the furnaces, although some form of multiple temperature records should be used to inform the operator of the conditioning of the steel in preparation for soaking. The same equipment is needed for recuperative temperature—waste gas in and out—and preheated air. To protect the exhauster from possible damage from excessive air temperature, temperature control equipment should be installed to control a cold air bleeder positioner to insure that the preheated air temperature be held below a point which would be dangerous to the furnace.

From the furnace we but naturally go to the hot mill for following the temperature of the heated metal through its course of milling. The matter of taking the temperature of fast moving hot bodies is of much more recent development than other forms of pyrometry but instrument manufacturers have devoted a lot of energy to this problem and now we can state that this equipment can measure the temperature of the strip accurately and can reach a full scale reading on the recorder in 3/5 of 1 second. With speed like this available, every variation along the length of the strip can be measured and the sheet temperature can be obtained and to end as it passes the turn table.

While we are on a discussion of hot mill equipment it would be well to make some mention of recording equipment for detecting the temperature of bearings. This equipment is perhaps more essential for such installations as use roller bearings where the actual temperature of the bearing ring will determine the ultimate effect of metal fatigue and failure. This equipment, where it has been supplied, is usually in the form of a four record instrument to record the temperature at the top and both sides of the bearing for the backing up roll and the bottom and both sides for the bottom backing up roll.

The next unit of operation for which equipment is necessary is the continuous pickling lines and the batch picklers. With the development of the continuous line of covered acid or hot water wash tanks, and the accuracy of governing solution concentrations it has been entirely fitting that pickling control should have been developed far beyond its early conception of control thermometers. When it is realized that most continuous pickling lines are to be operated with the temperatures held within plus or minus 3° it can be realized that the equipment once used for continuous picklers would no longer be satisfactory. The only essential is for accuracy and this means thermocouple and potentiometer measurement of the temperature. No less than the best equipment should be installed for this duty even though it is not an exact metallurgical heat treating process. The cost of acid and steam is enough to warrant exact control even if the metal surface treatment did not. All of the new continuous pickling lines have been equipped with potentiometer controls and the results have been most gratifying.

From the pickling line the material is then moving to cold reduction and annealing processing and, of course, the annealing departments may be constituted of a great many different type of furnaces. Regardless of whether the installation is of the radiant tube portable furnace type or in and out box annealing, the control required has practically always been of the automatic type. However, whether automatic or hand regulated the equipment should be properly grouped into central control rooms and properly protected against the dirt and dust usually present as the result of the furnace movement and sand or stone seals. There have been some especially fine installations worked out, some of which involved control and some of which are of the smaller panel type but the tendency in all recent installations has been to group the equipment from 4 to 8 furnaces together and have a number of control rooms in the annealing department.

The use of the radiant tube fired furnace has introduced some very interesting temperature problems which involve not only the metallurgical treatment of the steel, but the protection of tubes against excessive temperatures. The high cost of alloy tube replacements would be an important item of maintenance if they were subjected to temperatures beyond the usual requirements of annealing. Therefore, it becomes the function of the control to eliminate these tube temperatures under all circumstances and in so doing the principle treatment on the steel is produced because while excessive tube temperatures may not develop a fault in steel structure if they only occur for short intervals, but they may overheat the edges of the steel and cause stickers in the outer coils or along the edges if the load is flat.

On all furnaces of the radiant tube type there has been developed an interlock between tubes and steel temperature. In the type of furnaces required two position firing operation this interlock is affected so that if either tubes or steel are high in temperature, the control valve is moved to its minimum position. The development of these central panel boards has also enhanced the development of special types of plug switches and receptacles for both thermocouple and control circuits, all of which has materially aided in the central control operation.

With the Annealing Department work there are a

number of gas generating machines of various types to produce the reducing atmospheres required for steel surface protection and the proper determination of the properties of this gas has been a problem particularly interesting to the industry. There has been developed a recording equipment of the thermo-conductivity principle which can be used to determine whether the gas is oxidizing or reducing and the intensity of the reducing properties. Since the reducing properties of the gas are dependent on te hydrogen and carbon monoxide contents and it has been found that these two properties of gases when developed at elevated temperatures are correlated, any recorder which can detect the quantity of hydrogen in the gas will really measure its effective properties as a reducing agent. In general, most of the gas machines can well utilize such a check as this and the equipment should be arranged so that each individual gas generating machine can be analyzed as well as the main line.

The continuous normalizer for strip or sheet steel will embody a number of zones of control and it has been a generally accepted principal that if the furnace for this purpose is over and underfired that each zone of control should have separate instruments for the firing over and under the sheet, that is, two controllers per zone. Since the normalizing furnace is invariably subject to considerable load variation, temperature controllers for this particular duty should be of the load compensating type.

There are several equipments on normalizers, which while not exact innovations, have not generally all been combined on the same furnace. It is the writer's idea that these units should be a part of every normalizing installation and they are listed as follows:

1. Single record radiation pyrometer for taking the actual temperature of the strip immediately before the curtain wall at the end of the heating zones.
2. A recording tachometer to indicate the speed in inches per minute travel of the strip.
3. A system of atmosphere analysis is almost an essential in modern normalizing furnaces to determine the efficiency of burner setting, combustion regulation and furnace tightness.
4. If the normalizing furnace is for handling very wide strip, an indicating instrument should be provided with thermocouples along the outside edges of the strip to determine if the lateral temperature distribution is correct. This instrument has an additional excellent use to provide a reading from all thermocouples in case of current failure.
5. The fuel to this type of furnace as well as any other should, of course, be recorded and integrated and a meter should be on the main panel board for the normalizing furnace to show this quantity.

With the exception of instruments for recording grease system pressures and humidity of coil storage and warehouse, this practically completes the instrumentation of a continuous strip mill. Of course, in such processing as sheet galvanizing or tinning are followed into as part of the mill equipment for these units may be properly considered part of the mill equipment.

Ingenious galvanizing settings have been developed which pickle the material, dry it, galvanize it and stack it. Naturally temperature control of both picklers and spelter operations are required and equipment for this purpose should be included.

For tinning operation the control of the temperature of the tin and palm oil baths are absolutely essential and it is generally conceded that these should be of the best potentiometer type of controls available. The necessity of close regulation of these temperatures emphasize that these equipments should be recording potentiometers which they have not generally been in the past. The tendency is certainly toward the recording type of equipment in these units and also toward the equipment which will recognize the heating requirements of various tin gauges in both tin and palm oil gas.

Our last comment on strip mill instrumentation is that with equipment as complete in its scope, and therefore, necessarily intricate, as has been used in most of our continuous units the prime consideration on instrumentation should be the set up that is made for the care of the equipment. Very early in the construction stages of the mill, it seems wise to create a department for this purpose and designate someone as in complete charge of this work. This department should function from the first day that installation of any control equipment starts so that the men in it are familiar with how this equipment is installed and then as the mill starts to run, what it will do. At this stage there will be no questions about the functioning of the equipment, and therefore, no long delays when maintenance or adjustment is required.

PART 2 - By R. H. ELLIS

▲ A FEW weeks ago at a meeting of the Association of Iron and Steel Engineers in Pittsburgh, Professor Trinks, in reviewing 40-year progress of the Steel Industry, stated that, basically, steel was now being made much the same as in the past and that the greatest change was in the methods of production. Professor Trinks' most important change was indicated as the use of electric motors, and at this time it is intended to discuss, not the use of the motors, but to enlarge on the use of instruments which analyze the behavior of these motors.

Early mill installations of electrical equipment consisted of a wound rotor motor running at a continuous speed and the conditions affecting the operation of this motor were of little interest, except perhaps, to the electrical maintenance man. As a result, no visible signs of meters were to be found in the mill and very few installations boasted meters in the motor pit.

Therefore, the mill man in general had a great lack of respect for any meter or indicating device whatsoever, and insisted that rolling steel was beyond the need of such technical assistance.

However, things changed, speeds increased, accuracy of product was demanded, rough shod methods were condemned, and today the meter is an integral part of the mill, and as important as the roll.

The continuous hot strip mill, with its variable speed motor, now is equipped with central operating pulpits

in which complete speed and power indicating meters are installed. The motor rooms are provided with graphic meters and the more modern mills are installing on the mill floor, graphic or indicating meters for the use of roller. The roughing mill, at its central pulpit, although not equipped with speed indicators, has its quota of power meters and, in the case of the edger rolls, their speed and powers are indicated. On slab pushers at broadside mills it is very important that load meters be mounted at the operator's pulpit to aid him in the proper operation of the slab pusher, as this machine is not supposed to do the mill motor's work and it is imperative that only the proper value of push be maintained.

The hot run table and coilers are two very important locations where speed and load meters are essential. Hot strip traveling at two thousand feet per minute is not to be trifled with and the coilers and table must be perfectly matched.

Thus, electric meters have become an important part of the hot mills. The cold mills, although less spectacular, have perhaps enjoyed even a more rapid rise to fame. Speed jumped from one hundred to fifteen hundred feet per minute and above. Tension reels were installed, tandem mill back drags, automatic uncoilers, etc. Here the speed and power meters were again pressed into service, but also, automatic devices, unseen by the mill operator, are the real reasons for the success of the cold mill. Tension regulators, the heart of the cold mills, have been developed from the original Terrill regulator to high speed vibrating units. Tension measuring units are now available to read the strip tension between stands; flying micrometers to measure the thickness of the material being delivered from the rolls; all combining to improve product and speed up production.

Besides purely technical requirement, some aids for the physical benefit to the operators have been installed; one of which has been the use of the so-called "productimeter". This unit replaces the mechanical dial indicators which, with the advent of large housings, climbed into almost unreadable heights, and so, by the use of selsyn ties and counters, the screwdown indication was brought down to the operator's eye level. Beyond the physical benefits, this unit actually gives a better reading than the old dial. It reads, for instance, in cold mill work, directly by the use of numbers to one tenth of one thousandth of an inch and also reads the actual opening of the roll, whereas the old dial lost its value after one complete turn.

Selsyn units are also now being used throughout the mill for other purposes. One important use is to transmit signals from hot mill coiler to finishing mill roller; giving a quick, accurate story regarding the size and condition of the steel, thus doing away with the old "arm waving" signals.

One very interesting and important development is the pressuremeter for indicating the static load on a mill housing developed by the screwdown. This unit, primarily developed during the time when bearing capacities were not all to be expected, and when too much load was detrimental to the bearings and shortened their life, has now, due to improvement in bearing design, found a new use. These units can be used to indicate the preset loading of a mill, which, when rolling cold thin material such as tin plate, can provide a means of "setting up" the mill for proper reduction without the use of trial coils. For example: Rolling from .072" to .010" in a 4-stand tandem mill, all the rolls are set below the zero opening, that is to say:—the mill housing is stretched. Now after new rolls are inserted in the mill, the operator, from his past experience, knows the proper amount to stress his mill housing in advance of rolling so that the proper drafts are obtained.

THE CHEMISTRY OF LUBRICATION

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Abstract of paper to be presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28-29, 1938.

▲ AT first thought it would appear that there would be no justification for a paper on the subject "The Chemistry of Lubrication." This thought is only natural, since the application of chemistry to lubrication has been increasing so gradually—one might almost say subtly—that it has hardly been noticed. This change has been similar to the addition of one inch to a ten foot rod; the addition is hardly discernible. However, as inch after inch is added at regular intervals, the time comes when the additions are not only noticed but are strikingly apparent. So with chemistry in lubrication. Its application was so gradual that it was accepted as a matter of course. Now, however, the chemistry of lubrication is not only a necessity but a boon to industry. It is only with a knowledge of what can happen that such happenings can be aided or prevented and the application of chemistry to lubrication furnishes part of this knowledge. The expression "part of this knowledge" is used advisidly since chemistry alone does not solve problems. It is only by the application of all knowledge, physical, mechanical and chemical, that the efficiency of lubrication is increased.

This subject is too large to be covered completely and entirely in this paper so only a few of the more important phases, particularly those encountered in the steel mills will be discussed.

The chemical structure of the molecules of a petroleum lubricant is known to be complex but relatively speaking the exact structure, with but few exceptions, is unknown. This condition obviously makes the problem of forecasting performance more difficult so improvement comes only as a result of research and experience.

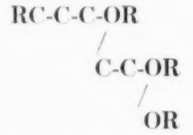
Circulating oils have been in use for many years; however, their use is still being extended and, further,

the demands made on the oil are becoming more severe. The application of chemistry has resulted in making available products better able to meet the demands. There are certain requirements circulating oils must meet and when expressed in terms of characteristics of the oil, they are:

1. The correct viscosity to furnish adequate lubrication without excessive fluid friction.
2. A pour test sufficiently low to insure fluidity at any temperature that may be encountered in the installation.
3. A good demulsibility to permit removal of water which gets into any system.
4. A high stability to insure resistance to oxidation and sludging.

It is particularly in demulsibility and stability characteristics that chemistry is involved. Unquestionably, other things being equal, the less polar the compounds, the better the demulsibility.

The word "stability" has been used so loosely that it may not always convey the desired meaning. In this discussion it will be used to cover resistance to deterioration, oxidation and sludging of an oil in service. In a circulating oil this characteristic is of prime importance and cannot be stressed too strongly. The oil is being attacked continuously by oxygen so an aldehyde may result, and then a keytone and so on. This oxidation reaction continues until a complex branch chain high molecular weight oxygenated compound results. Such a compound might have the following structure:



The amount of oxidized oil can be determined since it is essentially insoluble in Naphtha (Hexane) but soluble in chloroform. Since this oxidation may continue until sludges or even coke results, circulating oils should be checked regularly to determine the amount of oxidized oil present. Another check is determining the neutralization number since as the oil oxidizes to acidity this test will show the change.

The actual deterioration cycle in a circulating system therefore would be about as follows: Unsaturated compounds in the presence of air oxidize to form acids. These acids react with metals to form metallic soaps. These soaps and sludges may deposit in the system and restrict the oil flow, thus causing an increase in temperature. They cause an increase in viscosity and therefore more fluid friction so there is an increase in temperature. The rate of oxidation is influenced tremendously by temperature. As a matter of fact the rate of oxidation doubles for about every 20°F rise in temperature. The rise in temperature due to oxidation causes more rapid oxidation so a vicious circle results which keeps on and on until the oil is no longer fit for use.

Obviously the more resistant it is to oxidation the longer an oil can be expected to last. The following illustration is typical of an oil with a good stability:

Length of Service	Vis. — 100	Neut. No.	Naphtha Insoluble	Chloroform Soluble	Ash
1 Month.....	2037	.05			
12 Months...	2051	.19	.02	.01	.005

This oil is in a Morgoil system in a Hot Strip Mill and, if the same precautions of removing dirt and water are continued, can be expected to give years of satisfactory service.

The most stable Circulating oils are secured by refining the oil to give molecules which are as nearly as possible saturated straight chain hydro-carbons.

In addition to the process of refining, addition agents may be used. Materials which tend to prevent the reaction of oxygen on the product are inhibitors. Unfortunately most inhibitors are water soluble and therefore not usable. Many are polar and themselves unstable in the presence of heat. There are however, inhibitors which can be used in certain oils for specific types of work which give excellent results.

The lubrication of a turbine is a typical example of the use of low viscosity circulating oil. Most turbine oils are highly refined products with good stability and can be expected to give a few years service before they oxidize to the point that makes them unfit for service. A highly refined inhibited turbine oil however will last indefinitely. A typical illustration of an oil that has been used continuously in a 7500 KW. turbine follows:

Length of Service	Neutralization No.	Tag Robinson Color	Vis. — 100
Original Oil.....	0.03	21	150
11 Years.....	0.04	12	148

There are other addition agents besides inhibitors which have great merit. A typical example being solublizers such as have been found so effective in Diesel engine lubricating oils. Solublizers are products which when used with properly selected oils prevent the deposition of partially oxidized and otherwise gummy and tarry products. In this instance oxidation does occur but the products of oxidation do not separate or deposit to give the hard carbon, stuck rings, etc., so common in Diesel operation.

No paper on the chemistry of lubrication would be complete without some comments on that very controversial subject of extreme pressure lubricants. There are many theories as to the why and how of E. P. lubricants, but regardless of the one being discussed, they all include a chemical reaction. Thus in this field which has done much to give improved designs the proper application of chemistry has resulted in progress.

Unquestionably the future will see increased concentration on the chemistry of lubrication and a continual improvement in the quality of the lubricants available to industry.

WHEN LUBRICANTS MUST STAY PUT... STEEL PICKS

PENOLA

WHERE pressures up to 5,000,000 pounds per bearing are developed in rolling operations . . . where lubricants must not break down and run out, must insure perfect protection by staying put on the job, steel picks Penola. Because Penola Extreme Pressure Lubricants meet these exacting conditions perfectly, more than 85% of all continuous-mill roller bearings now in service are Penola lubricated. Steel makers have learned that Penola means quality specialized lubricants for every steel mill operation. That is why Penola makes and sells more steel mill lubricants than any other maker in the world.

PENOLA LUBRICANTS

PENOLA INC., PITTSBURGH, PA.
[Formerly Pennsylvania Lubricating Company]

NEW YORK · CHICAGO
DETROIT · ST. LOUIS

LUBRICANTS FOR THE STEEL INDUSTRY SINCE 1885.

NEW STRIP WELDER AT GRANITE CITY

▲The installation of a strip welder of a new type has just been completed by United Engineering & Foundry Company at the Granite City Steel Company, Granite City, Illinois.

This unit follows the mechanical principle of the welder installed by United at the Ford Motor Company several years ago in that the shear is retractable and the unit is mounted in a recoiling line. The new development at Granite City is the use of the Linde automatic gas head for welding.

One large steel producer in the West has been hand welding with gas for several years with great success, and the Granite City installation is to further develop that success through the use of mechanical means for handling and shearing the strip, and the application of automatic control to the welding heads.

This recoiling and welding line at Granite City is placed in the line of production between the United rotary pickler and the United 48″ reversing cold mill previously described in the "United Effort".

The oiled coils are brought from the rotary pickler and placed in the coil box at the entry end of the recoiling and welding line.

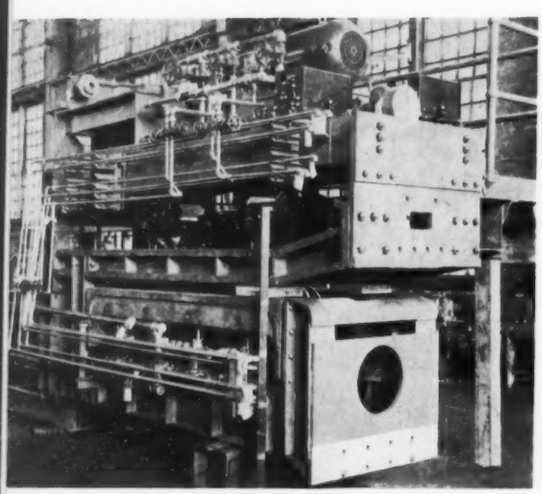
The strip is fed from the uncoiler through an uncoiler-leveller into the combination shear and welding head. This shear is the open throat upcut type and is retractable, and after the back end of the leading strip has been sheared and the forward end of the trailing strip has been sheared and matched, the shear unit moves back away from its position and at the same time pulls the welding head into place.

This combination shear and welding head is mounted a few degrees off the right angle position with reference to the movement of the strip, in order to provide a skewed weld. The principle of the skewed weld is to prevent the sudden bump of the entire surface of weld meeting the work rolls of the cold mill at one time. This theory is similar to the driving of an automobile across railroad tracks where the driver will approach the tracks at a slight angle to prevent the sudden impact of wheels striking the rails at the same time.

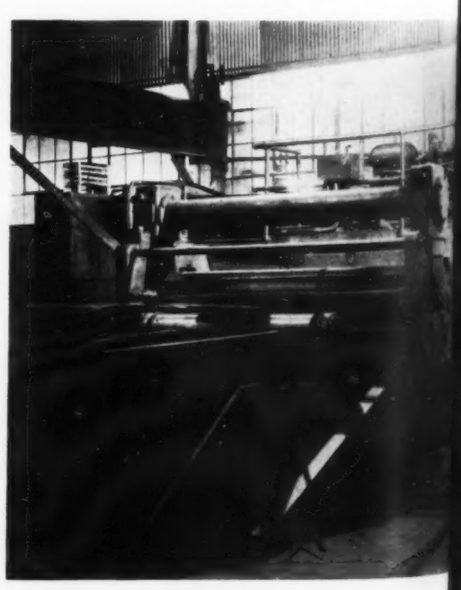
The details of operating this line can be explained as follows:

A pickled coil is placed in the coil box and the outside end is fed into the uncoiler-leveller. The shear is in the pass line at this time and the first end is cropped. This end is fed through the back tension rolls and on to the mandrel of the recoiler where it is gripped in the drum. This first coil is then run through to the end where the hydraulically operated clamp operates to hold the strip and its trailing end is cropped by the shear. The sheared end is left above the pass line so that the leading end of the second coil may be run through

Linde-United gas welder and clamps with end for attachment to shear in the foreground.



Coil box and uncoiler-leveller at entry end of recoiling and welding line.



Delivery end of tight coiling welder line. Oxy-acetylene welder is shown in the line with shear retracted.

the shear, clamps set, and this leading end cropped and matched.

The ends of the two coils to be joined by welding are now in the throat of the shear and each end is held by an hydraulic clamp to prevent misalignment prior to, or during the welding operation. The shear cuts have been made at an angle of approximately three degrees with the longitudinal pass line, so that in subsequent cold rolling the entire length of the weld will not hit the rolls at one time as described above.

The next operation involves moving the shear out and the automatic gas welder into the line to weld the sheared ends. This is accomplished by motor operated traverse gears with the shear-welder assembly moving on a track at 87 degrees to pass line. With the welder in position, its clamps are actuated to permit the two coil ends to be held by an additional clamping device at about 10" from the weld traverse line.

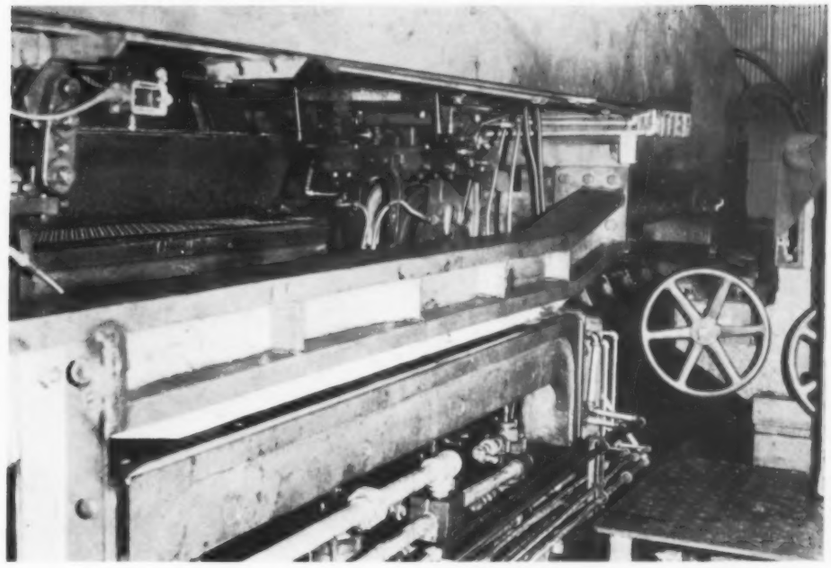
The welding is accomplished by automatically controlled multiple tip oxy-acetylene blow pipes. The welding heat is automatically controlled by photo-electric cell to give the correct penetration from top to bottom.

After the weld is completed, the top and bottom heads automatically separate and the now completely joined ends of the two coils are run into the side clippers. Here the unmatched ends caused by the difference in strip widths are clipped out in a quarter moon pair of dies and the joined coils run on through the back tension rolls and on to the recoiler mandrel.

Where three or more coils are to be welded together, the operation of the shear and welder is repeated as required.

The objects attained by this Linde-United oxy-acetylene type of strip welder are as follows:

1. Great reliability of welds with reference to going through the cold mill without breaking.
2. Avoiding possibility of marking work rolls by absence of hard metal in or adjacent to the weld.
3. Elimination of necessity for flash stripping or grinding weld after it is made.
4. Speed suitable for operation in a recoiling or processing line.



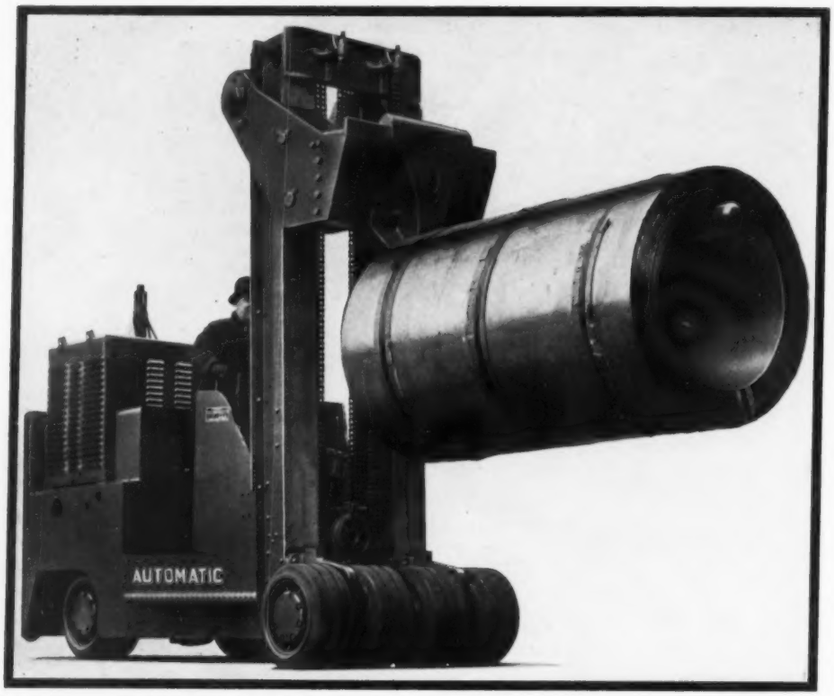
Linde-United Automatic Gas Welding Head

The welded and side clipped coils are rewound on the mandrels for the 48" reversing cold mill.

SOAKING PIT VALVE

▲ Several years ago the American Manganese Steel Division of The American Brake Shoe & Foundry Company, Chicago Heights, Illinois, in collaboration with a Chicago district steel mill, developed a new type mushroom valve for use on ingot soaking pits. Now, after two years of service, it has been definitely ascertained that these new type valves of Amsco Alloy will render long time, economical service.

In this test installation, Amsco Alloy mushroom valves weighing 80 lbs., replaced cast iron valves weighing approximately 800 lbs., a saving in weight of 90%. The iron valves had to be water-cooled to operate efficiently for any length of time. In spite of this water-cooling, the iron valves scaled badly from oxidation which soon resulted in a poor seal, and because of poor seating air leaked into the furnace and caused excessive scaling of the steel ingots being heated for rolling.



Ram and fork tractor capable of transporting the new wider welded type coils 84″ to 96″ long, and weighing 20,000 to 30,000 lbs.

CENTER CONTROL RAM AND FORK TRACTORS

▲ Anticipating the new requirements of continuous strip mills for super-service tractors having capacities far greater than ever before attempted in this mobile type equipment, the Automatic Transportation Company of Chicago, Illinois, has "again been first" to pioneer new development by building the World's greatest capacity and most compact center control ram and fork tractors.

In operation these new ram and fork tractors will facilitate the ultimate in efficient, flexible transportation and storage of the new wider welded type coils 84″ to 96″ long, weighing 20,000 to 30,000 lbs. representing a maximum rating up to one million, one hundred twenty-five thousand inch pounds.

These new tractors symbolize super-strength, simplicity, compactness and dependability in every respect. They are designed with many unique engineering features acquired through many years' experience and consultation with operating executives of steel industries.

The outstanding feature of this new tractor is "Steer-o-matic drive", designed to provide the ultimate in driving and steering efficiency. This is a combination drive unit and motorized steering turntable, controlled automatically—separately by remote power steer and fully remote contactor control with automatic drive acceleration from operator's station. This unit is a radical departure from the conventional type drive used in industrial trucks and is geometrically correct in that tire drag, pinching or crowding are eliminated whether the tractor is standing still or in motion with maximum load.

Operating executives will welcome the fact that in this new "Steer-o-matic-drive" there are no universal joints, no steering knuckles, rods or connections to cause trouble.

In construction, the drive unit is a powerful and highly efficient double reduction spur gear transmission powered by a super-service duty motor. Power is transmitted through extra wide-faced heat treated chrome nickel steel gears and pinions mounted on shafts with self-aligning ball bearings. Extra large diameter chrome nickel steel full floating drive axles are used; these are fitted with splined ends, and are heat treated for high tensile strength and driving torque. Wheels are fitted to axle housing with extra large adjustable roller bearings. The complete drive unit is mounted to steering turntable, with a pivoted connection for fully equalized traction to compensate for uneven runways and to relieve main frame from torsional strains or stresses.

Forward and reverse speeds are accomplished by remote contactor control from operator's station arranged for fully automatic acceleration and smooth tractive pick-up. Power feed to the drive unit motor is through the turntable by means of an insulated central rotor-ring having constant-tension stator fingers with full limit control for either direction.

The motorized turntable mechanism combined with the drive unit is a self-contained entirely enclosed gear unit, powered by a separate motor and controlled from operator's station by remote power steer, without any steering rods, joints or connections. The steering action is surprisingly easy for maneuvering with maximum loads.

The arrangement of the load wheels on this new tractor are likewise an outstanding engineering feature. These are "quadri-mounted", that is, four abreast. This is also unique in design, in that this arrangement not only permits more compact chassis construction, but eliminates the necessity of articulated frame construction or tandem mounted axles. Also, this method permits much larger diameter wheels with wider faced tires and thus provides a straight line of rubber 48″ across the entire front of the tractor for maximum rubber under full load, plus equalized axles to compensate for eneven runways.

Another feature highly desirable from the standpoint of economy in maintenance and service is that all wheels, tires and wheel bearings are fully interchangeable.

Considering the great capacity of this new tractor, 15 ton, the compactness of design can be emphasized in the wheelbase of only 90″ and a turning radius of only 125″, also, an overall length so short that the tractor will operate in a right angle aisle of 139¼″. These are actually less than smaller capacity coil tractors of competitive make.

The massive all steel frame is fabricated into one unit of super-strength by hot riveting and uni-welding process. One piece heavy section high carbon rolled steel plates form the main side body. These are riveted and welded to supplementary

members, such as rear bumper and alloy cast steel axle members. This forms a chassis of great structural strength capable of withstanding exceptionally heavy load strains.

In conclusion, this new automatic super-service ram or fork tractor offers the Steel Industry a mobile type of equipment with every feature for efficiency, accessibility and economy in operation.

LOW COST ALL STEEL HOME OPENED

▲ With the opening for public inspection of the first Blaw-Knox all-steel experimental home at 114 Pennsylvania Avenue, Clairton, near to the new Irvin Works of the Carnegie-Illinois Steel Corporation, details of materials and construction were made public.

While officials stated that design was aimed toward the development of a low-cost home, this was not done at the expense of good materials, good workmanship, or the neglect of proper insulation, comfort and appearance, essential for a present-day dwelling.

The house, which is of colonial design with a gabled roof, is 44 feet 2 inches wide by 24 feet 2 inches deep, containing approximately 900 square feet exclusive of porches. It is pointed out that the house is only one of a large number of possible designs, since the use of standard steel panels permits a wide range of planning for four, five, or six room homes.

The unit now open to the public has a living room 17 feet 9 inches by 13 feet 1 inch, a kitchen 14 feet 5 inches by 10 feet 0 inches, a utility room 8 feet by 10 feet, a master bedroom 11 feet 1 inch by 13 feet 1 inch, a guest bedroom 10 feet 6 inches by 10 feet 0 inches, a bath 8 feet by 6 feet, and a side porch 10 feet by 7 feet, with a covered front entrance.

All steel fire safe construction, which is termite proof and provides a high degree of insulation as well as a low cost, has been employed. The house has been built on a foundation of concrete blocks resting on concrete footings carried below the frost line. The floor is laid on a reinforced four inch concrete slab using 2 inch by 4 inch wood sleepers spaced 16 inches on centers. With the exception of the utility room, which has a concrete floor trowled smooth and level with the other floors, all are of yellow pine, sanded, stained, and varnished; the floors of the kitchen and bath are covered with standard linoleum.

An outstanding feature of the Blaw-Knox home is in the exterior walls which are constructed of standard size insulated panels of wall height. These are made in prefabricated units either 40 inches or 20 inches wide, so that complete flexibility of design within the limits of the employment of these units is possible.

The panels consist of a steel frame of rust-resisting copper-bearing steel channels welded together. The interior and exterior surfaces of the panels are then covered with metal clad, one inch water-proof rigid insulation, thus forming an enclosed three inch air space. The panel is then completed with copper-bearing formed steel sheets laminated to the insulation with a rust-inhibitive asphalt emulsion cement.

The fabricated panels are delivered ready for erection, with a shop coat of metal priming paint, and provide a smooth finish for both interior and exterior walls without the use of exposed bolts, welding, or screws.

No cutting is required to form windows or doorways, as all panels are fabricated to the exact size required and can be quickly erected with special connectors furnished.

The walls rest on a foundation sill or base angle of copper-bearing galvanized steel, which is attached to the foundation with $\frac{3}{8}$ inch by 6 inch bolts. A $\frac{1}{8}$ inch asphalt felt weather strip is cemented to the under side of the base angle to form a seal next to the foundation. The wall panels are securely bolted to the base angle and to a wall cap. Special wedge shaped brackets and stud connectors hold the panels securely in place.

All the interior partitions are constructed of channel studs placed 16 inches on centers with channel wall caps and floor plates; both faces of the partitions are covered with $\frac{3}{8}$ inch sheet rock, using reinforced metal "A" joint system and crack filler.

The roof framing consists of double steel channels welded together. The truss members are bolted together, cross braced, and bolted to the heavy gauge top plates of the side walls. They are designed to carry maximum loads on clear spans of 24 feet.

The bottom cores of the trusses provide the support for the metal

Newly designed all steel house by Blaw-Knox Company, erected for public inspection at Clairton, Pa.

clad insulated ceiling panels which are attached with clip brackets and Helyx nails.

All roof surfaces are completely insulated with one inch asphalt impregnated rigid structural insulation attached to roof, trusses, and cross bracing.

The roof covering is of galvanized standard seamed panels. Special design of the ridge, ridge cap, and panel caps, provides an absolutely watertight roof.

Standard steel ventilated type casement sash with wood trim is used for all windows. Interior and exterior doors are of wood with wood frames and trim. Front and side porch materials are of steel with ornamental welded steel columns. Base interior ceiling cornice molds are of wood. The kitchen is supplied with a 52 inch single drain-board apron-type sink of porcelain enamel iron as well as with built-in cabinet and counter units which are completely assembled and factory enameled ready to set in place. The cabinets consist of one wall unit 36 inches wide, as well as a 42 inch counter unit and a 36 inch counter unit.

The water, gas, and drainage systems are installed complete, according to code requirements. The plumbing is complete with a wall lavatory, five-foot bath tub, vitrous-china toilet, and two section slate composition laundry tubs. The automatic gas water heater has an insulated storage tank. All fixtures are equipped with single chromium plated brass fittings.

Heat is provided by a gas fired heater and winter air-conditioner, giving a completely automatic warm air circulating system that heats, filters, humidifies, and purifies the air.

Wiring is complete in flexible conduit for fixtures, switches, base plugs, and utility outlets. The electric fixtures are of modern colonial pattern with the owner permitted to make his own selection within the allowance included in the contract price.

The interior and exterior color scheme can be selected by the owner. Interior wood work and doors are given a three-coat enamel satin finish. Walls and ceilings are painted with a stipple finish. All exterior metal and wood surfaces are given three coats of paint.

NEW POLYPHASE INDUCTION MOTOR

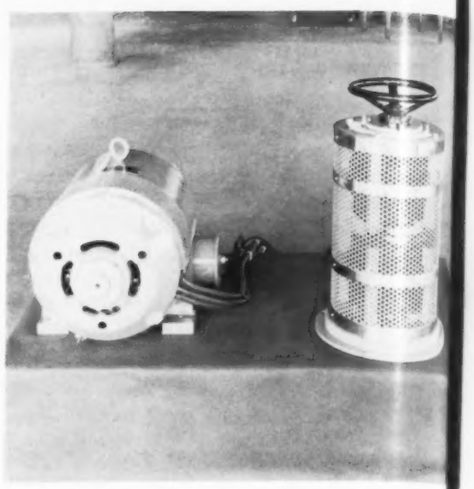
▲ A polyphase induction motor having characteristics similar to a direct-current shunt motor has been developed by the Crocker-Wheeler Electric Manufacturing Company of Ampere, New Jersey. The motor, which is known as the "polyspeed" motor, is capable of being operated at an infinite number of speeds between zero speed and 1720 rpm. At present the motors are available in sizes up to 7½ HP., for operation on 220, 440 or 550 volts, three phase, sixty cycle.

Features include: Fully continuous speed regulation without rheostat losses; speed practically independent of the load, constant torque through the entire speed range; high starting torque—up to 400 percent; full-load starting torque with little more than full-load starting current; full-voltage starting; dynamic braking; remote and automatic control of speed, if desired.

Regulation of speed is obtained by applying a "bucking" or an "aiding" voltage to the motor brushes. The stator core and winding of the motor is similar to that of an induction motor, while the rotor is similar to a direct-current motor armature. The adjustable voltage to apply to the motor brushes is obtained by means of the induction-type voltage regulator shown at the right in the accompanying illustration.

If the adjustable voltage is exactly equal and opposite to the voltage generated in the rotor by the revolving magnetic field, no current will flow in the rotor and the rotor will remain stationary. If the bucking voltage is gradually reduced, current will flow in the rotor, torque will be developed, and the rotor will come up to a speed corresponding to the regulator setting. By adjusting the bucking voltage, the motor can be made to run at any speed from standstill to a speed slightly below the synchronous speed of 1200 rpm. By a further adjustment of the regulator an aiding voltage is applied to the brushes making it possible to run the motor through synchronous speed and on up to 1720 rpm.

Operation at speeds below 600 rpm. is possible for short periods of time only without some external source of air for cooling.



Polyphase induction motor having characteristics similar to a direct current shunt motor.

LARGEST ALL-WELDED MILL-TYPE CRANE

▲ The Cleveland Crane and Engineering Company, Wickliffe, Ohio, has built what it says is the largest all-welded mill type crane ever constructed. The crane is one of fifteen that are being built of the same span and design. It is 120-ft. span and weighs 137½ tons. Every major section, such as the two girders, the four end trucks, trolley, cage, etc., are fabricated into rigid one-piece units by welding. No rivets were used. Bolts were employed to tie the major sections together because of shipping and erection limitations.

One of fifteen all welded cranes of the same span and design reputed to be the largest ever constructed.

WESTINGHOUSE *Personnel* CHANGES

Westinghouse Electric and Manufacturing Company has announced a realignment of the Industrial Department. Three new departments, Industrial, Resale and Industry Engineering have been formed to meet the changing conditions in industrial markets.

The new Industrial Department has a staff of field trained sales engineers each of whom has had broad experience with industry problems. The electrification of industries such as iron and steel, mining, chemical, petroleum and public works will be served by this department.

The Resale Department will devote its facilities to servicing manufacturers whose products incorporate electrical equipment and other secondary distribution channels such as industrial agents and jobbers. However, those companies building equipment for a specific industry will remain the responsibility of the Industrial Department. Such activities as machinery electrification, appliance electrification, and construction industries and contractors will be included in the new department.

Backing up both departments with application engineers, the Industry Engineering Department will provide a corps of engineers experienced in electrical problems of the several industries. In this capacity the department will have a true engineering approach to industry electrification and its engineers will be available for consultation and development work.

The various managerial changes in the Industrial Department are as follows:

C. B. Stainback, formerly assistant manager of the Industrial Department, has been made manager of the realigned department. Mr. Stainback will maintain headquarters at the East Pittsburgh plant.

Bernard Lester was made the manager of the Resale Department. Mr. Lester formerly was assistant manager of the former Industrial Department. His offices will be in Pittsburgh, Pennsylvania.

C. A. Powel has been appointed manager of the newly formed Industry Engineering Department. Mr. Powel, who has been associated with the company since 1919, was born in 1884, in Rouen, France. He was educated in England and Switzerland, being graduated from the Institute of Technology of Bern. In 1905, he entered the application engineering department of Brown, Boveri & Company in Baden, Switzerland. Six years later he was sent to Japan as resident engineer for that firm and remained there until 1915, when he returned to England and joined the civil branch of the Ordnance Department. Following the World War he moved to Pittsburgh and joined the Westinghouse Company. Previous to his recent appointment, Mr. Powel was manager, Central Station Engineering Department.

The new Industrial Department will consist of six industry sections: Metal Working; Mining; Petroleum and Chemical; Public Works and Communications; General Mill; and Marine Electrification. The managers for the various sections are:

Leslie M. Gumm, new manager of the Metal Working Section, will be in charge of electrification of steel mills and automotive plants. Mr. Gumm comes to his new position from the Chicago office where he has been in charge of similar activities for the Northwestern District. He is a graduate of the University of

C. B. STAINBACK

BERNARD LESTER

C. A. POWEL

LESLIE M. GUMM

J. S. PARRY, JR.

Q. M. CRATER

J. H. JEWELL

G. D. BOWNE

Illinois, 1916, and since then has been associated with Westinghouse sales work.

J. S. Parry, Jr., newly appointed manager of the Mining Section, is a graduate of Princeton, 1920, and since then has been associated with Westinghouse sales work. Since 1924 he has been located in the New York office, first as salesman and since the early part of 1937 as eastern district general industry supervisor.

Q. M. Crater, new manager, Petroleum and Chemical Section, was graduated from Purdue University in 1927. He has served Westinghouse in various field and headquarters sales capacities. He comes to his new position from the sales department of the Steam Division.

J. H. Jewell was made manager of a new section known as Public Works and Communications Section. Included in its scope are public works, communications, amusements and relations with architects and consulting engineers whose major work identifies them with the above industries. Mr. Jewell is a graduate of Pratt Institute, 1920, and since that date has been associated with Westinghouse sales at headquarters and in the Middle Atlantic district. Since 1928 he has had charge of the construction section at Philadelphia, Pennsylvania.

G. D. Bowne, who has been manager, General Mill Electrification Section, continues in that relationship. Included in this section are important industries such as paper, textile, food and rubber.

These appointees will all be located at the East Pittsburgh plant of the Westinghouse company.

The newly formed Resale Department will promote the use of company products among machinery manufacturers and other secondary distribution channels. This department will be divided into three sections: Machinery Electrification, Appliance Electrification and Construction Section. Those responsible for the activities of the department are:

W. D. Turnbull, manager, Machinery Electrification, will head the development and handling of company business with machinery manufacturers, the same responsibilities he held under the former Industrial Department. Mr. Turnbull entered the employ of the

J. M. STAPLES

L. F. A. MITCHELL

A. C. MONTEITH

R. D. EVANS

company in 1923 upon graduation from Pennsylvania State College. He served in various capacities in the general engineering department as mining engineer and in charge of petroleum engineering activities. For a number of years he headed up the sales to these industries. In 1931, he became manager of Machinery Electrification for the former Industrial Department.

J. M. Staples was made manager of the Appliance Electrification Section, heading a new section responsible for the household, office and store appliance manufacturers' industries. Mr. Staples has been with Westinghouse since 1927, when he was graduated from the Virginia Polytechnic Institute. After training he was for some time in headquarters sales, and from 1932 to 1936 with the Westinghouse Supply Company He returned to the Industrial Sales Department in early 1936.

L. F. A. Mitchell continues as manager, Construction Section. Mr. Mitchell is responsible for general contractors, electrical wiring companies and heating, ventilating and other contractors. Previous to that he was assistant manager of sales for the Canadian Westinghouse Company. Mr. Mitchell has wide experience in the selection and application of electrical equipment in all industries including the construction field.

These appointees will also be located at the East Pittsburgh offices of the Westinghouse company.

The new Industry Engineering Department has been formed to centralize electrical engineering activities of the company relating to central station and industrial power problems. Listed below are the personnel changes in the formation of this new department:

A. C. Monteith becomes Engineering Manager, Central Station Section. Mr. Monteith has been with Westinghouse since he was graduated from Queens University, Ontario, in 1923. He completed his Westinghouse training in 1924, and at once entered upon central station engineering work.

R. D. Evans and C. F. Wagner become consulting transmission engineers. Both are well known in the central station industry and both have been engaged in Westinghouse central station or related engineering work since completing the training course. Mr. Evans is a graduate of the University of Oklahoma, 1914, and Mr. Wagner of the Carnegie Institute of Technology, 1917.

The industrial activities are divided among three sections: The Metal Working Section; the Mining, Chemical and Petroleum Section; and the General Mill and Resale Section.

G. E. Stoltz was made manager, Metal Working Section in this new industry engineering department. Mr. Stoltz has been with the company since graduating from the Ohio State University in 1909. He has been closely identified with steel mill electrification developments and mine installations of the Westinghouse company.

Phelan McShane becomes manager of the Mining, Chemical and Petroleum Section. Mr. McShane joined Westinghouse Company in 1922 having previously been associated with leading steel, mining and transportation companies. With Westinghouse he has been identified with Westinghouse general and commercial engineering work with the steel, construction and equipment industries.

C. W. Drake will manage the General Mill and Resale Section. Mr. Drake was graduated from Worcester Polytechnic Institute in 1905, and since then has been identified with Westinghouse application engineering work with the miscellaneous industries from headquarters, except for the years 1914 to 1919, when he was located in the Chicago office.

H. C. Coleman continues as manager, Marine Engineering Section.

All the sections of the Industry Engineering Department will be located at the East Pittsburgh plant of the Westinghouse Electric and Manufacturing Company.

C. F. WAGNER

G. E. STOLTZ

PHELAN McSHANE

C. W. DRAKE

ADVERTISING PAGES REMOVED

ITEMS OF INTEREST

John A. Stephens was made director of industrial relations for the United States Steel Corporation of Delaware. Mr. Stephens has been with United States Steel subsidiaries since 1934, when he started as a sales student at the Illinois Steel Company's plants in Gary and South Chicago. He had previously held important executive positions with several business organizations in the East. After a short period as sales student he transferred to the general sales department and then to the staff of the operating vice president. When the Carnegie and Illinois Steel companies were joined in October, 1935, Mr. Stephens was appointed manager of industrial relations, Chicago District, the position he had held until the present time.

▲

John B. Mitchell has been appointed superintendent of rolling mills, Pittsburgh Works, Jones and Laughlin Steel Corporation. P. H. Devaney will take his former position at the Aliquippa works as superintendent of blooming, billet, and bar mills, 10-inch skelp and 14-inch merchant mill.

▲

H. C. McCaughy, chief engineer of the Apollo Steel Company, Apollo, Pennsylvania, has been made general superintendent. Frank Oppenheimer has succeeded Mr. McCaughy as chief engineer, and W. H. Richey has become assistant general superintendent, chief chemist, and metallurgist.

▲

J. A. Amos was elected president of the Pyle-National Company, Chicago, Illinois, at the annual meeting of the board of directors. Mr. Amos has been a vice-president of this company for the past twelve years. He succeeds Mr. William Miller, who was elected chairman of the board.

Theodore J. Kauffeld, chairman and managing director of Inter-Continental Engineering Company, Limited, Shell-Mex House, Strand, London, W. C. 2, is making a tour of inspection of the various steel companies in the United States of America. Mr. Kauffeld is acquainting himself with any new systems or new plants that have been developed since he left Pittsburgh in October 1936. While in this country Mr. Kauffeld has established headquarters at the Metropolitan Club in Pittsburgh, Pennsylvania.

The London Company represents De Laval Separator Company of 168 Broadway, New York City. Mr. Kauffeld is also a director of Steel Mill Design and Construction Company, Ltd. He has been a member of the Association of Iron and Steel Engineers for several years.

▲

J. W. Wagoner, formerly general manager of the Salem Engineering Company, has been appointed vice president in charge of all operations, both sales and production. Mr. Wagoner will be in complete charge of operations at the home office in Salem, as well as Pittsburgh, New York City, Welland, Ontario, London, and also in the company's offices on the continent.

▲

W. H. Wiewel was made assistant general manager of sales for Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania. Mr. Wiewel will supervise the general activities of by-products and pig iron, sheets and strip, tinplate, and tubular products sales departments. He came to Jones and Laughlin in 1935 as manager of sales of tubular products. He entered the steel business in 1910 with the former Cambria Steel Company.

(*Please turn to page 83*)

J. A. AMOS

T. J. KAUFFELD

J. W. WAGONER

H. J. Watt was appointed assistant general manager of sales for the Jones and Laughlin Steel Corporation's Eastern district sales offices. Mr. Watt will have charge of New York City and the East, with general supervision over district sales offices in Boston, New York, Philadelphia, Atlanta and the new district sales office in Baltimore. Mr. Watt has been district sales manager in New York since 1935. He entered the steel business in 1912 in the Philadelphia office of the former Carnegie Steel Company and came to Jones and Laughlin in 1925.

▲

Several promotions and new appointments were recently announced by Lewis M. Parsons, vice president and general manager of sales of the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania:

Arthur A. Wagner, former assistant manager of hot rolled sales, becomes manager of hot rolled sales, succeeding Mr. R. T. Rowles.

John O. H. Anderson, former assistant district sales manager in New York City, became manager of sales, tubular products, succeeding Mr. W. H. Wiewel. Mr. E. J. Dickson becomes assistant manager of sales, tubular products in Pittsburgh, Pennsylvania.

V. A. Jevon was made district sales manager of the Baltimore office of Jones and Laughlin Steel Corporation. Mr. Jevon is a new man in the Jones and Laughlin organization, coming from the Baltimore office of the Bethlehem Steel Company,, where he had been assistant manager of sales since 1933. H. R. Dorney will be assistant district sales manager of the Baltimore office of the Jones and Laughlin Steel Corporation.

▲

John B. DeWolf was appointed district sales manager in Philadelphia, succeeding Thomas C. Ham, who was transferred to Pittsburgh to supervise the Corporation's industrial training plan. Mr. DeWolf was formerly assistant manager of tinplate sales for Republic Steel Corporation in Cleveland, Ohio. He entered the steel business in 1912 with the Liberty Steel Company, which subsequently merged into Republic Steel Corporation.

▲

Herbert B. Spackman was made assistant district sales manager at Philadelphia. Mr. Spackman is a newcomer in the Jones and Laughlin organization. He had been with the Bethlehem Steel Company since 1923 in the sales departments at Buffalo and Philadelphia.

▲

Edward H. Hughes has been appointed district sales manager at St. Louis, succeeding J. B. Hungate, who resigned. Mr. Hughes entered the steel business in 1912 with the American Bridge Company and in 1916 started with Jones and Laughlin in the Chicago warehouse. In 1934 he became assistant manager of sales, steel construction at Pittsburgh, Pennsylvania.

▲

R. T. Rowles has been appointed assistant general manager of sales, having general supervision over product sales departments of the Jones and Laughlin Steel Corporation. Mr. Rowles will supervise the general activities of the hot rolled, cold finished, wire products, and warehouse sales departments. Mr. Rowles started with Jones and Laughlin Steel Corporation in 1912. In 1925 he was appointed manager of hot rolled sales, holding this position until his present appointment. He will be located in the Pittsburgh headquarters of the Corporation.

▲

Charles J. Maher was appointed assistant general superintendent of the H. C. Frick Coke Company, with headquarters at Uniontown, Pennsylvania. He succeeds W. C. Hood who on January 15, became general superintendent of the United States Coal and Coke Company.

▲

Officials of the United States Steel Corporation of Delaware recently made a tour of inspection of the major improvements in the Corporation's construction program in the Birmingham, Chicago and Pittsburgh districts.

Included in the group were Myron C. Taylor, chairman of United States Steel Corporation of Delaware; E. R. Stettinius, chairman of the finance committee; William A. Irvin, vice chairman of the Corporation; E. M. Voorhees, vice chairman of the finance committee; J. Carlisle MacDonald, assistant to the chairman of the Corporation; and B. F. Fairless president of the Corporation. This trip was in the nature of a farewell tour for Mr. Taylor as his resignation as Chairman of the board became effective April 1, to be succeeded by Mr. Stettinius.

Concluding the survey at Pittsburgh, the group toured the Irvin Works, the new slabbing mill at Edgar Thomson Works, Braddock; the site of the Gilbert and Varker housing development in Clairton; the new warehouse occupied by Union Supply Company; and the executive offices of the United States Steel Corporation of Delaware, at 436 Seventh Avenue.

Officials of U. S. Steel visiting Irvin Works, Carnegie-Illinois. Reading from left to right, W. A. Irvin, vice chairman; Myron C. Taylor, chairman, now succeeded by E. R. Stettinius, Jr.; B. F. Fairless, president; H. G. McIlvried, general superintendent, Irvin Works; E. M. Voorhees, chairman Finance Committee; E. R. Stettinius, chairman; J. L. Perry, president, Carnegie-Illinois; J. E. Lose, vice-president of operations, Carnegie-Illinois; and J. C. MacDonald, assistant to chairman, U. S. Steel.

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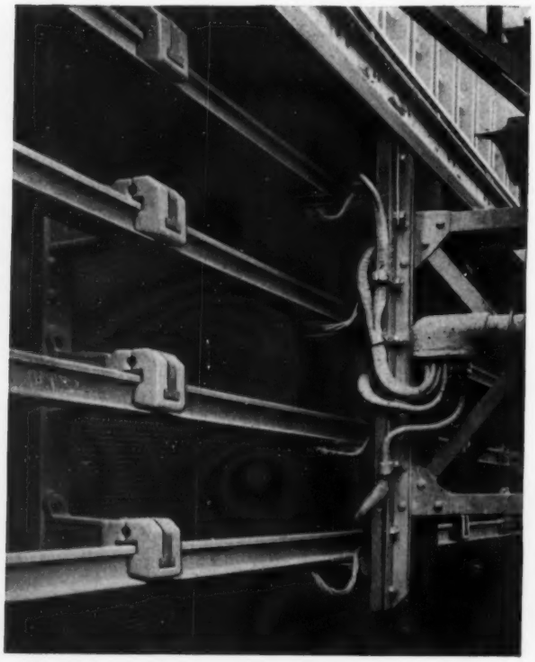

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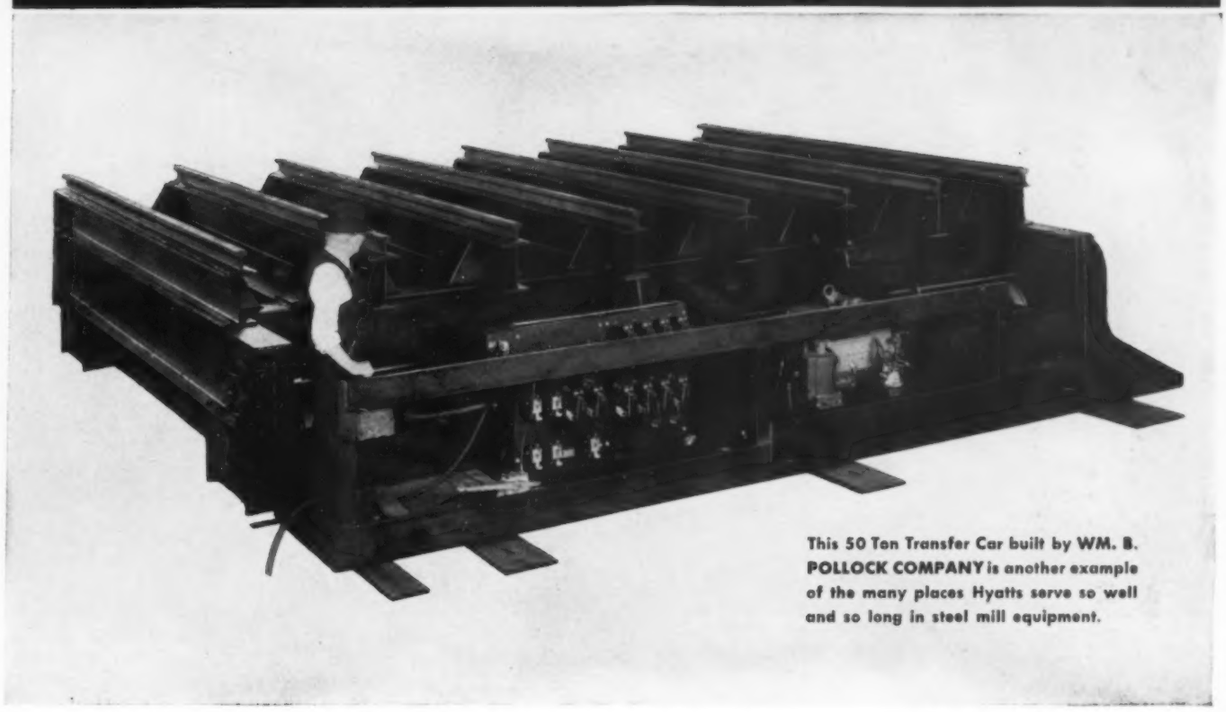
Agencies in Principal Cities and Foreign Countries

WHERE *Performance* COUNTS...



This 50 Ton Transfer Car built by WM. B. POLLOCK COMPANY is another example of the many places Hyatts serve so well and so long in steel mill equipment.

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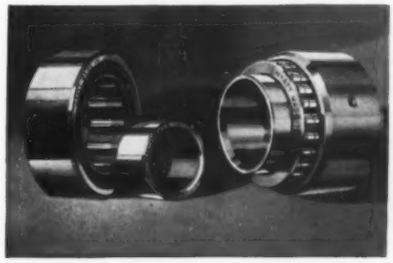
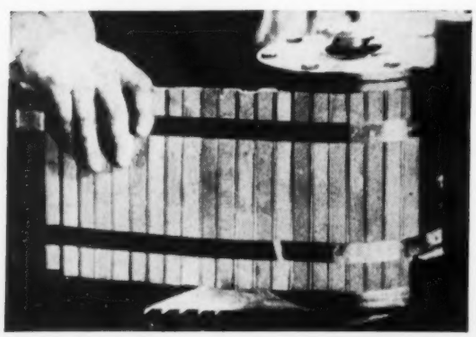
HYATT performance writes an indelible story. Performance expressed in extremes . . . load extremes, time extremes, economy extremes. Made of sturdy stock, and tough to the core, each Hyatt race and roller is steeled to meet the most exacting conditions of operation. Nowhere else in the world is steel so carefully selected to do a specific job, and so carefully controlled in manufacture, as in the Hyatt plant at Harrison, New Jersey. That's why most of the mechanical equipment operating in the steel mill is today more efficient, more dependable, more economical, and much longer-lived because Hyatt Roller Bearings are written into design and specifications wherever endurance and economy are factors. Therefore, consider Hyatt performance before you write *your* specifications. Hyatt Bearings Division, General Motors Corporation, Harrison, Detroit, San Francisco. Hyatt Roller Bearing Sales Company, Chicago and Pittsburgh.



HYATT ROLLER BEARINGS

JAMES WATT...THE GENIUS

1 From this crude model, an exact replica of Watt's original steam engine, came the greatest industrial and social revolution the world has ever seen. Actually, the principle of the steam engine had been discovered 30 years before, but the original model was so imperfect it could do no useful work. Watt improved its efficiency ... invented the valve action that doubled its power . . . found out how to convert its reciprocating motion into rotary motion . . . and devised the governor to keep its power under control. The industrial age was under way . . .



2 Constantly searching for further improvements in his engine, Watt soon saw that heat escaping through the cylinder walls was wasting fuel and power. So he applied a band of wooden strips around the cylinder . . . one of the first known uses of industrial insulation. Crude as this type of insulation was, it was immediately effective. The same amount of fuel gave more power . . . the efficiency of the engine was greatly increased . . .

3 Asbestos, in the time of Watt, was known only as a curiosity . . . a "magic mineral," dense as rock, that could be fluffed out into silky fibers and woven into cloth that was unharmed by the hottest fire. At right is shown a thin vein of asbestos in the rock in which it was formed ages ago. Today, due largely to pioneering research by Johns-Manville, asbestos is made into many types of insulating materials for a wide variety of purposes.

4 A far cry from Watt's crude wooden strips is this scientifically designed insulation for the boiler of a giant locomotive that gets more power from a pound of fuel than Watt ever dreamed of. The insulating material is Johns-Manville 85% Magnesia, for many years the standard insula-

5 Watt knew his wood strips reduced heat losses, but he did not know why. We have since learned the real reason . . . the efficiency of a material in retarding heat flow depends primarily on the number of small cells per unit of thickness. About 1900, a remarkable new insulating material was discovered in California . . . a vast deposit of the skeletons of tiny sea organisms, called diatoms. More than *40 million* of these minute shells are contained in each cubic inch of diatomaceous earth. Processed by Johns-Manville, this material, known as Celite, is made into some of the most efficient high-temperature insulations known today.

WHO STARTED THE AGE OF STEAM

tion in the moderate temperature (600° F.) field. 85% Magnesia is made from dolomite limestone, chemically converted into magnesium carbonate and combined with asbestos fiber into blocks and pipe insulation. Steam lines, boilers, oil-refinery fractionating apparatus and many other types of industrial equipment are effectively protected against heat waste with this J-M Insulation.

Industry as we know it today began in 1765, the year James Watt developed the first practical steam engine. With this unlimited source of mechanical power at his command, man finally escaped from monotonous, backbreaking methods of doing the world's work. Human energy was directed to more constructive tasks, and during the next century civilization made more progress than in all the ages since the dawn of history.

Watt's engine ran by heat, and it wasted far more than it used. Seeking to improve it, he hit on the idea of wrapping a jacket of wooden strips around the cylinder. This is one of the first known uses of industrial insulation . . . the beginning of the idea of conserving heat and fuel.

For more than a century, however, insulation was not considered important. Fuel was plentiful . . . heat losses from boilers, furnaces and exposed pipes were taken for granted. But as the use of heat in industry broadened into new fields and as industrial processes improved, operating efficiencies and production costs were more closely watched. The vital need for effective insulation was recognized.

Today, wherever heat or refrigeration is employed in industry, insulations are also used. And economical, efficient insulating materials are now available for use throughout the entire range of temperatures used in industry—from far below zero to 3000° F. and more above.

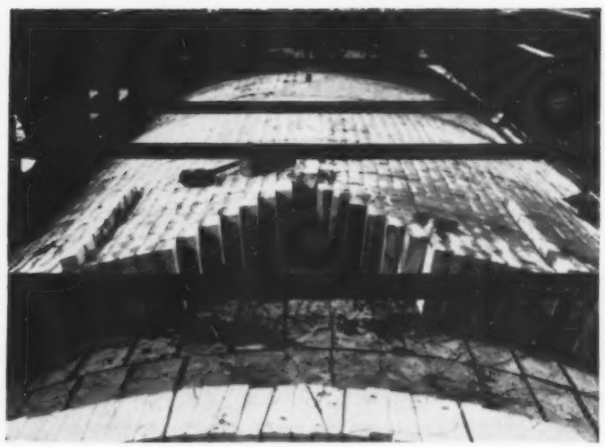
Since its beginning 80 years ago, Johns-Manville has pioneered in the development of a great number of the insulations which industry uses today. Part of the story is told on these pages . . . for detailed information on J-M Insulating Materials and recommendations for the solving of various insulation problems, ask for the J-M Industrial Insulation Catalog. Johns-Manville, 22 East 40th Street, New York, N. Y.

Johns-Manville

INSULATIONS FOR EVERY TEMPERATURE

...FOR EVERY SERVICE CONDITION

6 This soaking pit wall is being insulated with Superex Block—a highly efficient insulation made of Celite bonded with asbestos fiber. Superex, also manufactured in pipe-covering form, is recognized as the outstanding insulation for superheated steam lines and for conserving fuel and improving performance on slab-heating, annealing and all types of controlled-atmosphere furnaces, producer-gas mains, hot-blast stoves, open-hearth furnaces and regenerators.



7 Other J-M Insulations made from Celite include the well-known Sil-O-Cel materials—Sil-O-Cel Natural and C-22 Brick, Sil-O-Cel Powder and Sil-O-Cel C-3 Semi-Refractory Insulating Concrete. The walls and roof of the normalizing furnace shown above are built entirely of Sil-O-Cel C-22 Brick used as a combination insulation and refractory—a construction which makes possible thinner furnace walls and improved performance. There is a J-M Insulation for every steel-mill requirement.

ADVERTISING PAGES REMOVED

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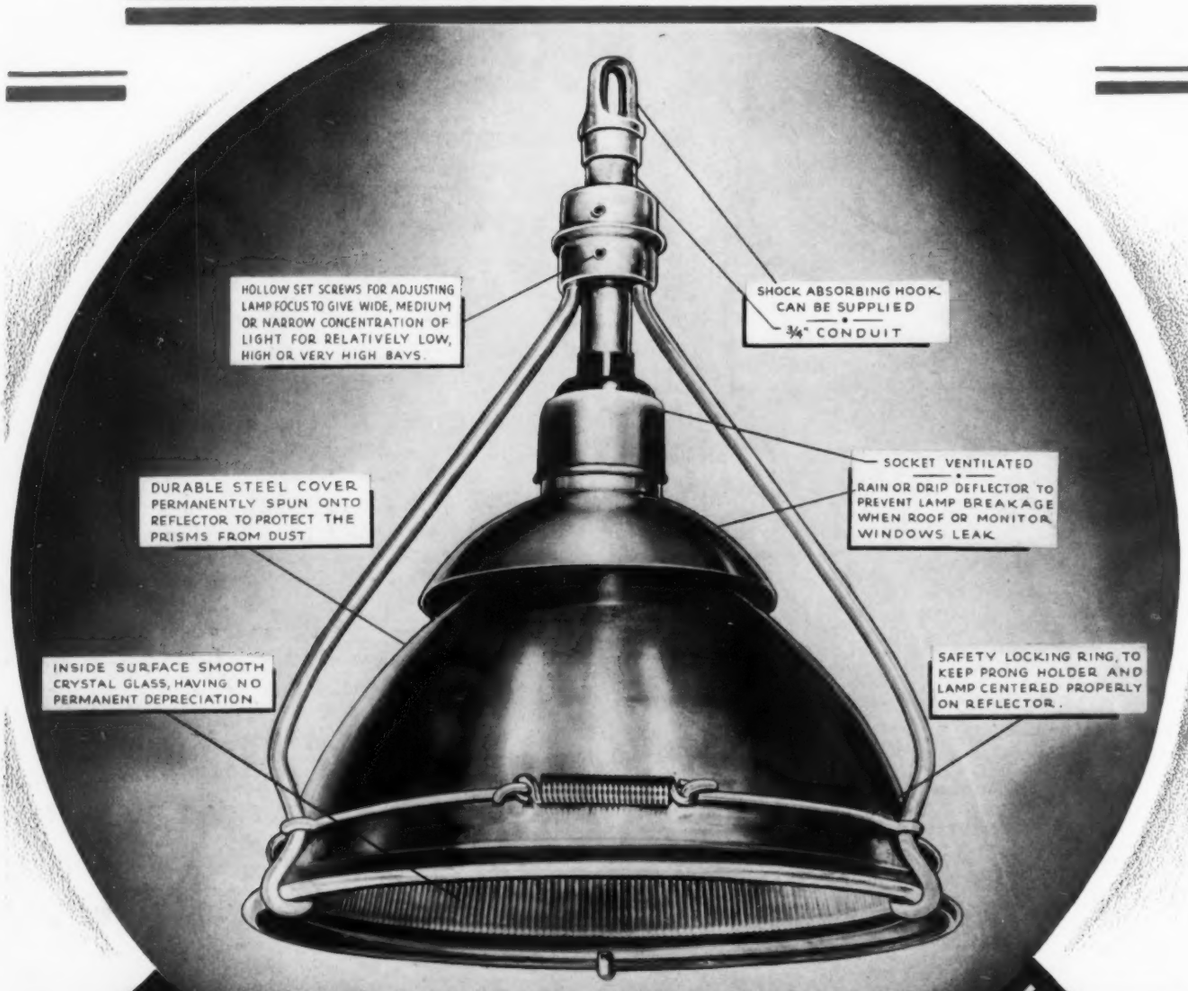
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